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Contributors to this Issue

Bardenbacher, R.
Siemens-Schuckertwerke Aktiengesellschaft
Abteilung Allgemeine Entwicklung

Brandstetter, A.
Siemens & Halske Aktiengesellschaft
Wernerwerk für Fernsprechtechnik

Fröhr, F.
Siemens-Schuckertwerke Aktiengesellschaft
Abteilung Allgemeine Entwicklung

Haffa, A.
Siemens-Schuckertwerke Aktiengesellschaft
Technische Stammabteilung

Homp, J.
Siemens-Schuckertwerke Aktiengesellschaft
Technische Stammabteilung

Hübner, G.
Siemens & Halske Aktiengesellschaft
Hauptwerbeabteilung

Jaeschke, W.
Siemens-Schuckertwerke Aktiengesellschaft
Kabelwerk

Jäger, G.
Siemens-Schuckertwerke Aktiengesellschaft
Technische Stammabteilung

Murmann, D.
Siemens & Halske Aktiengesellschaft
Wernerwerk für Telegrafen- und Signaltechnik

Schmidt, R.
Siemens-Schuckertwerke Aktiengesellschaft
Technische Stammabteilung

Wahl, H.
Siemens & Halske Aktiengesellschaft
Wernerwerk für Fernsprechtechnik

Weik, H.
Siemens-Schuckertwerke Aktiengesellschaft
Technische Stammabteilung

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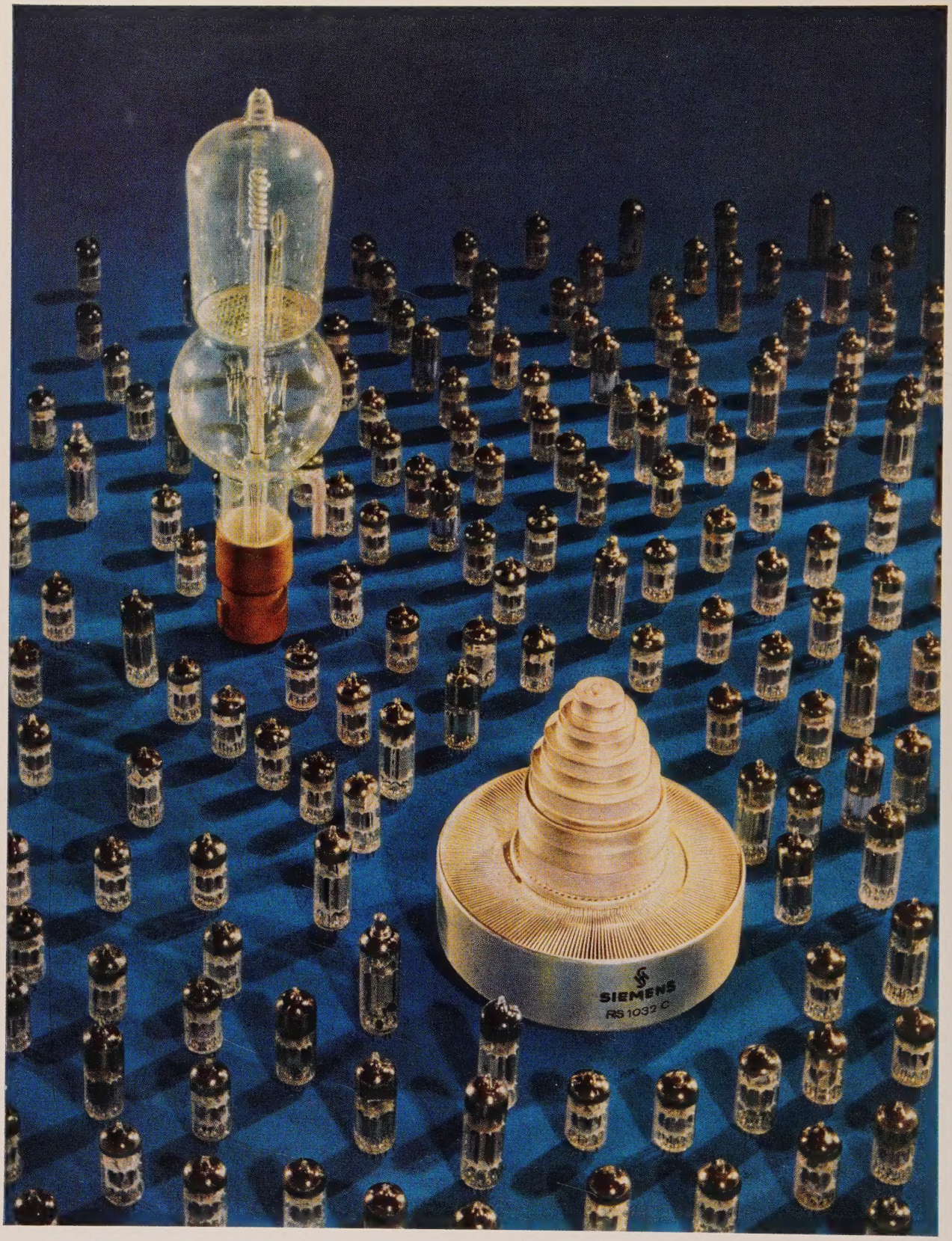

50 years of tube development by the Siemens organization lie between the Lieben tube and the modern RS 1032 C metal-and-ceramic encapsulated transmitting tetrode with a 10-kw power output in the frequency range up to 1000 mc

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Dynamic Braking of Pumped-storage Units

By Albrecht Haffa

Rapid shutdown is a feature desirable with most pumped-storage units, whether they be of the type with separate pump and turbine or of the reversible type. Since the retardation of machines of this kind may take as long as an hour, it is advisable to employ some form of brake.

Although mechanical brakes have long been used, they have certain drawbacks. This has prompted the recent application to large waterwheel generators, and particularly to the electrical machines of pumped-storage stations, of dynamic braking as employed on synchronous machines.

The function of every braking system is to convert the kinetic energy of the rotating masses into heat. Neglecting for the moment any artificial braking systems, retardation is effected by friction, particularly that due to water and air. With the gates closed, the turbine runner wades in the water-filled turbine casing (this applies to certain types only). If the level of the water in the draft tube has been depressed to permit, for instance, synchronous condenser operation, it can be raised to obtain the required friction effect, unless the turbine is of the Pelton type. The braking force applied to the turbine runner rotating in water decreases approximately with the cube of the speed. That due to windage of the rotor of the electrical machine is much lower and decreases approximately with the power 2.5 of the speed. Even lower is the bearing friction which in the majority of cases, i.e., when friction due to water is present, can be neglected altogether.

The friction losses described obtain on practically every shutdown operation. Since they are mainly effective in the upper speed ranges, they do not prevent long drawn-out retardation at low speeds, which is the very factor decisive for the duration of the shutdown operation.

It is here that dynamic braking can be employed to great advantage since its effectiveness increases with decreasing speed, as is described below. The additional braking torque is produced by the copper losses which arise in the stator of the synchronous machine and which by switching in external resistances can be increased further.

Circuit arrangement for dynamic braking

During dynamic braking, the stator of the synchronous machine is short-circuited directly or via external resistors. The rotor is excited so as to cause current to flow in the stator without normally exceeding rated current. Attention must be paid to temperature rise since the ventilation decreases with the speed. In the case of direct-connected exciters, the excitation current must be provided from an external source during braking, for instance, from the power station batteries or from rectifiers fed by the three-phase station-service system. If, on the other hand, the pumped-storage unit is equipped with a main-shaft-mounted auxiliary generator and a separately installed exciter set, the drive motor of the exciter set can simply be disconnected from the auxiliary generator and fed from the station-service system.

The basic circuit arrangement is shown in Fig. 1. It is based on the method described above with the auxiliary generator and separate exciter set since this has found particularly wide acceptance. The switches $S3$ and $S6$ are for switching over the exciter set to the station-service system. Via the closed de-excitation switch $S2$, the exciter energizes the field of the main machine. Arranged in the generator phase leads is the circuit with the short-circuiting switch $S4$ and, where required, the load resistor, behind which the three conductors are connected to form

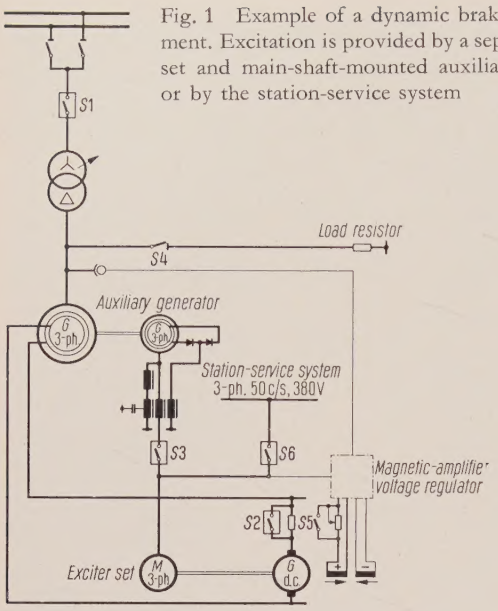


Fig. 1 Example of a dynamic braking arrangement. Excitation is provided by a separate exciter set and main-shaft-mounted auxiliary generator or by the station-service system

a star point. The magnetic-amplifier voltage regulator obtains its three-phase supply from the main-shaft-mounted auxiliary generator or from the station-service system. It has a positive and negative excitation output stage which feed the corresponding field windings of the exciter. Provided in the positive excitation arrangement is a resistance which is switched in during braking by the opening of switch $S5$ and which maintains the field exitation of the exciter at the preset value. If this were not carried out, the voltage regulator would go over to ceiling voltage.

The dynamic braking system operates as follows (see Fig. 1):

1. Braking is initiated (circuit breaker $S1$ is opened, guide-vane apparatus and globe valve are closed)
2. De-excitation is initiated (switch $S2$ is opened)
3. The exciter set is isolated from the auxiliary generator ($S3$ is opened)
4. Short-circuiting switch $S4$ is closed; the voltage regulator is set for braking excitation ($S5$ is opened)
5. The exciter set is connected to the station-service system ($S6$ is closed)
6. The de-excitation breaker is closed
7. Electrical braking commences.

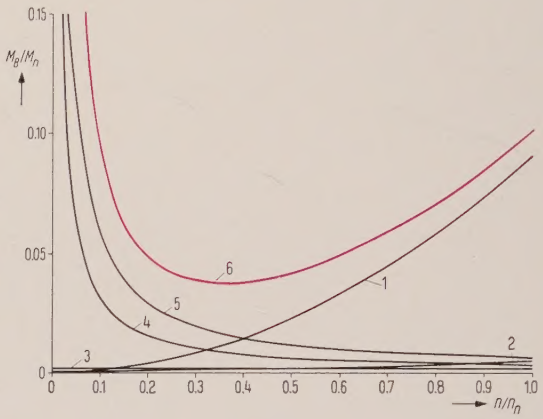
When the machine has come to rest, the exciter set is switched back from the station-service system to the auxiliary generator so that normal conditions obtain and the generator is ready for operation again.

Braking torques and their influence on the braking time

Table 1 provides a survey of the braking torques as a function of the speed, this being based on the equation

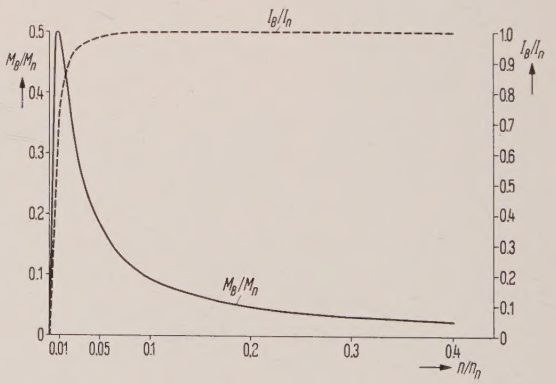
$$\text{Braking torque } M_B \sim \frac{\text{Braking power } P}{\text{Speed } n}$$

In Fig. 2*a* the braking torques are shown for a 35-MVA, 0.8-p.f., 10.5-kV, 375-r.p.m. pumped-storage unit. The unit is of the horizontal type with separate pump and turbine. It can be seen that where friction due to water is present, windage and bearing friction, including the supplementary losses, can be neglected. The figures are



a Ratio of braking torque to rated torque between rated speed and standstill

1 Braking torque of the turbine runner with casing full of water and gates closed
2 Braking torque due to windage and bearing friction
3 Braking torque due to supplementary losses in the generator
4 Braking torque due to stator copper losses on braking at rated current
5 Braking torque due to external resistance (200 kW at rated current)
6 Resultant braking torque obtained from the curves 1 to 5



b Resultant braking torque (——) and braking current (- - - -) at near zero speed with braking at rated current

M_B Braking torque
M_n Rated torque
n Actual speed
n_n Rated speed
I_B Braking current
I_n Rated current

Fig. 2 Braking torque characteristic between rated speed and zero speed for a 35-MVA, 0.8-p.f., 10.5-kV, 375-r.p.m. pumped-storage set

based on an external braking resistor of $R = 0.018$ ohms per phase corresponding to 200 kW at a rated current of 1,925 A. Important for braking in the upper speed ranges is the water friction while in the lower speed range the I^2R losses are decisive.

The performance of dynamic braking in the proximity of standstill is also interesting since the braking torque of the I^2R losses rises with falling speed and does not reach zero until immediately before zero speed is attained. A rough calculation can be carried out fairly simply.

Fig. 3 shows a vector diagram for a synchronous machine on a terminal short circuit. A small additional external non-inductive load resistance does not change the basic representation and merely introduces the effect of an increase in the resistance of the stator winding.

For braking at rated speed with the braking current i_{B0} we obtain from the vector diagram in Fig. 3*a* (p.u. values only)

$$e^2 = i_{B0}^2 \, x_d^2 \tag{1}$$

where $x_d \gg r$ and $r = r_i + r_a$.

For braking at any lower speed we obtain from Fig. 3*b*

$$e^2 \, s^2 = i^2 \, (r^2 + x_d^2 \, s^2) \tag{2}$$

where $s = n/n_n$

From the equations (1) and (2) it follows that

$$i = i_{B0} \frac{x_d \, s}{\sqrt{r^2 + x_d^2 \, s^2}} \tag{3}$$

The braking power p is given by (likewise p.u. values)

$$p = i^2 r \tag{4}$$

From the equations (3) and (4) we obtain the power for dynamic braking at the speed ratio s, where i_{B0} is the initial braking current at rated speed

$$p = i_{B0}^2 \frac{x_d^2 \, s^2 \, r}{r^2 + x_d^2 \, s^2} \tag{5}$$

Since the braking torque is now

$$\frac{M_B}{M_n} = m = \frac{p}{s} \tag{6}$$

the equation for the braking torque is given by

$$m = i_{B0}^2 \frac{x_d^2 \, s \, r}{r^2 + x_d^2 \, s^2} \tag{7}$$

In the torque curves shown in Fig. 2*a* the scale used did not permit indication of the maximum immediately before standstill. For this reason, the equation (7) for approximate standstill is again shown in Fig. 2*b*. It can be seen that the braking torque rises very sharply immediately before standstill.

It is interesting to determine the position and magnitude of the maximum braking torque.

Cause	Braking power	Braking torque
Turbine	$\sim n^3$	$\sim n^2$
Windage (generator rotor)	$\sim n^{2.8}$	$\sim n^{1.8}$
Bearing friction	$\sim n^{1.5}$	$\sim n^{0.5}$
I^2R losses in stator	constant	$\sim \frac{1}{n}$
I^2R losses in external resistor	constant	$\sim \frac{1}{n}$
Supplementary losses	$\sim n$	constant

Table 1 Relationship between braking power and braking torque as a function of speed

By differentiating the equation (7) with respect to s and equating it to zero we obtain the speed ratio s_m at which the maximum braking torque occurs

$$s_m = \frac{r}{x_d} \tag{8}$$

and by entering it in equation (7) we obtain

$$m_{\max} = i_{B0}^2 \frac{x_d}{2} \tag{9}$$

From these two results interesting conclusions can be drawn.

Equation (8) shows that the maximum is displaced further from zero as r increases, i.e., according to the value of the external load resistor for a given machine. The size of this is, however, limited by economic and technical considerations. If the maximum is displaced too far from standstill by overdimensioning the resistance, there is, despite the increase in the copper losses, the possibility that the machine will continue to rotate at very low speed and will not come to rest immediately.

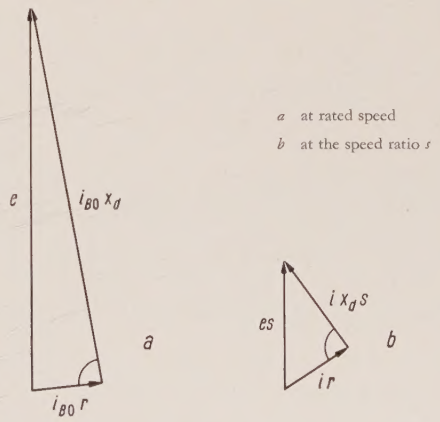


Fig. 3 Vector diagram for the synchronous machine on a terminal short circuit (not to scale)

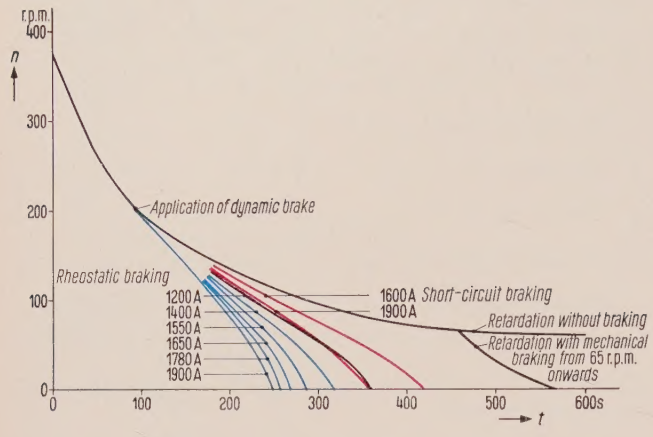


Fig. 4 Retardation curves for the 35-MVA machine. These were determined experimentally at various braking currents and without external resistance

Equation (9) shows that the maximum of the torque is not dependent on the resistance, i.e., on an existing machine it cannot be influenced by increasing the load resistance. If in the initial stage the braking system is operated at rated current, the ratio $M_{B\,max}/M_n$ is equal to half of the unsaturated synchronous reactance and is thus in general 0.4 to 0.6, an amazingly high value.

It is in this property that the main advantage of dynamic braking lies. As a result of the high braking torque the speed curve no longer approaches the time axis asymptotically, as is the case with normal retardation, but in the final phase drops almost vertically.

This can also be seen from the retardation curves obtained from the test (Fig. 4). In addition to this, they show the influence of the braking resistor. The machine concerned was the one with a rating of 35 MVA, already referred to. Down to a speed of 200 r.p.m. the curves are the same since it is not until this point that the dynamic brake is applied.

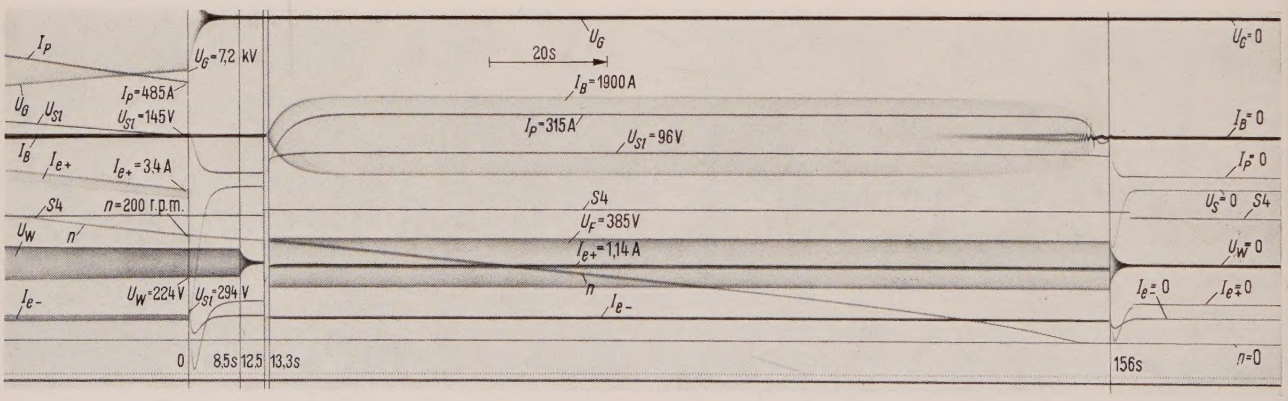
Automatic operation of the dynamic brake

In order to preclude the possibility of errors during the rather complicated switching operations, it is usual to fully automate the complete braking operation. Braking can be initiated by pressing a button on the machine house board or, in the case of emergency, automatically. The automatic application of the dynamic brake is generally limited to mechanical and hydraulic faults. Here, it is also necessary to make some of the generator protective gear inoperative.

Careful tests have shown that dynamic braking which is first applied at rated speed can in the majority of cases be dispensed with. In these speed ranges the friction due to water is predominant, as already stated. The application of the electric brakes would not be effective and would merely lead to heating of the stator and of the rotor.

Apart from this, it is expedient to wait until the last closing operation in the sequence guide-vane apparatus – globe valve – fill-up valve has been completed before applying the dynamic brake. By then the speed has generally decreased to approximately 60 %. The performance is, however, quite different if it is not possible to fill the turbine casing with water during the braking operation.

During the commissioning of the aforementioned 35-MVA pumped-storage unit, oscillograms were taken of the braking characteristics in order to provide an accurate survey of the conditions. Below is a detailed description of one of the oscillograms (Fig. 5). The circuit arrangement is as shown in Fig. 2.



U_G Stator voltage
I_B Stator current (braking current)
U_{Sl} Slipring voltage
I_P Field current
n Speed
U_W Voltage applied to induction motor of exciter set
U_F Voltage of the station-service system
I_{e+} Positive excitation current of exciter
I_{e-} Negative excitation current of exciter
$S4$ Position of braking switch

Fig. 5 Oscillogram of dynamic braking from 200 r.p.m. onwards with a braking current I_B = 1,900 A

Dynamic braking was initiated by hand at a speed of 200 r.p.m. (circuit breaker open; guide-vane apparatus, globe valve and fill-up valve closed).

$t = 0$ sec. De-excitation breaker opened; the generator voltage U_G practically attains zero in a few seconds. To permit oscillation de-excitation, the exciter set must remain connected to the main-shaft-mounted auxiliary generator.

The slipring voltage U_{Sl} of the generator transiently assumes a negative value (294V); the field current I_p falls to zero. Also the positive excitation current I_{e+} of the exciter is reversed and assumes a negative value.

$t = 8.5$ secs. After the voltage at the generator terminals has fallen to zero, the exciter set is isolated from the main-shaft-mounted auxiliary generator. The residual voltage across the terminals of the induction motor which drives the exciter set (U_W is the voltage at the induction motor) falls to zero.

$t = 12.5$ secs. The braking switch $S4$ is closed, thus switching in the external braking resistors (at the instant of switching there is a step in the curve $S4$).

At the same time the exciter set is switched onto the station service system ($U_F = 385$V) and the de-excitation breaker is closed.

$t = 13.3$ secs. The exciter set has started and the field of the generator begins to build up; after a short period the stator current attains the preset maximum value (1,900 A). The braking operation commences, the braking current remaining practically constant without the field excitation having to be reset.

$t = 156$ secs. The zero-speed impulse arrives from the machine. With regard to the speed curve on the oscillagram it should be noted that the threshold value of the measuring rectifier for supplying the speed-sensitive d.c. voltage distorts the oscillogram shortly before the machine comes to rest. For this reason the speed curve runs into the zero axis before zero speed is reached. Errors may also have been introduced into the curve for the stator current shortly before standstill.

The machine is now again de-excited and following this the exciter set isolated from the station-service system. From the curve for the braking switch $S4$ it can be seen when this switch is opened again. To return conditions to those originally obtaining, the exciter set is connected to the main-shaft-mounted auxiliary generator and the de-excitation breaker closed.

The machine set is thus ready for starting the pump. In automatic operation this takes place following completion of braking without any manual switching being carried out. With manual control the pumped-storage unit is ready for normal starting.

From rated speed a time of about 95 seconds elapses before dynamic braking is initiated at approximately 200 r.p.m., i.e., in the example the total time before the machine comes to rest is about four minutes. In view of the extremely high flywheel effect of the machine ($WR^2 = 7.59$ million lb-ft^2, inertia constant $H = 7$ secs.) this is a remarkable value.

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Relays for Telegraph and Signaling Equipment

By Dieter Murmann

The relay still to this day occupies a position of importance in electrical engineering. Although certain of its functions have now been taken over by amplifier tubes and transistors, steadily mounting production figures show that it is by no means an "obsolete" component. This growing output of relays generates in turn a requirement for extensive automation and quality control (Fig. 1), which on their part also depend on relays. The present paper briefly reviews the types of relays used in modern telegraph and signaling equipment and explains their design principles and features.

Common basis

Any form of electricity that is able to generate mechanical motion can be used to operate a relay. A distinction is made between electromagnetic, electrodynamic, electrostatic, thermoelectric, piezoelectric and magnetostrictive relays (Fig. 2). All relays are composed of an energizing

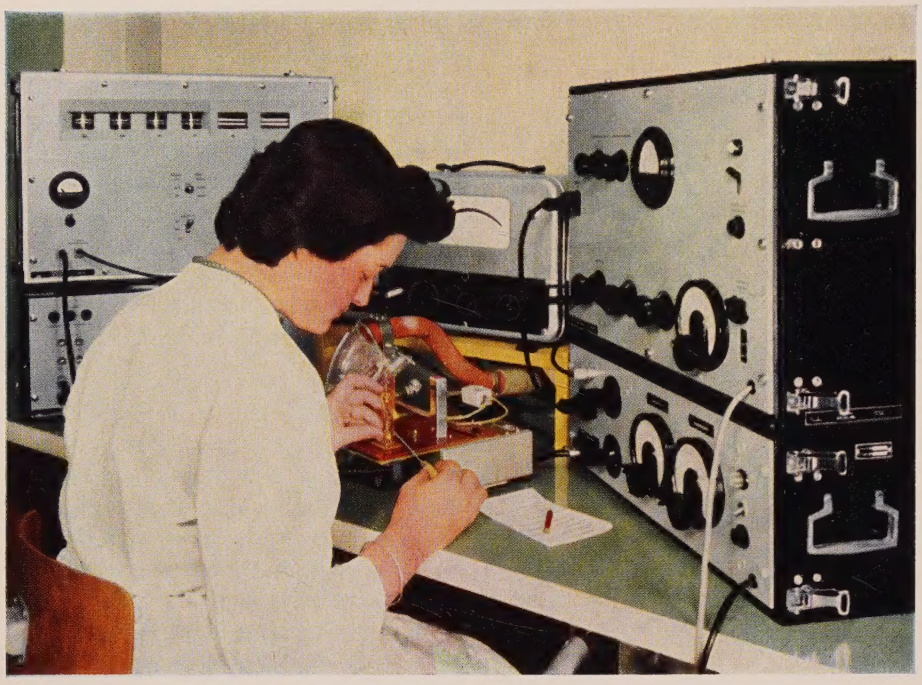


Fig. 1 Measuring setup for resonant reed relays

circuit and a contact circuit arranged with respect to each other in such a way that certain electrical values in the energizing circuit bring the contact system to set to defined positions. Energizing circuit and contact circuit are metallically isolated and can both be adapted in large measure to the given circuit arrangement. As a result of these features, relays can be used in solving a wide range of different problems.

The majority of relays used in communications operate on the electromagnetic principle. Of the two basic types of relay here found, one operates with nonpolar and the other with polarized energizing systems (Fig. 3). These differ in that, with a nonpolar system, contact make is independent of the direction of the energizing current flowing in the coil, whereas, with a polarized system, it depends upon the direction of this current.

Nonpolar electromagnetic relays

The energizing circuit of the nonpolar electromagnetic relay consists of a fixed yoke (frame or heelpiece), a core with energizing coil and a movable armature. The magnetic material used is soft iron.

When a current flows through the coil, the force

$$P = C_1 \, q \, B^2$$

acts upon the armature. C_1 denotes a constant that depends on the magnetic properties of the material, q is the cross section of the air gap, and B is the flux density or induction as a function of current.

Relays are usefully designed as lever-type armature relays, the design principle of which is shown in Fig. 3. As the force increases with decreasing armature spacing according to a square law, high contact pressure is obtained with a small armature travel.

It is usually required that the armature should directly follow the control processes in the energizing circuit. This cannot be effected at any desired speed because of the electrical and mechanical time constants of the relay. The smaller the electrical time constant, the greater the armature's force of attraction; the lighter the armature and the shorter the armature travel, the faster the relay will respond to the energizing current. If, on the other hand, a certain time lag is desired between the energizing circuit and the contact circuit, this may be realized by influencing the electrical time constant. This is accomplished by applying a short-circuit winding in which, in the event of a variation of the magnetic field, short-circuit currents are generated that oppose this variation. Time lags of up to several 100 msec can in this way be established.

Nonpolar relays are generally used wherever simple, budget-priced relays are required for control devices.

Midget d-c relay

A typical example drawn from the group of nonpolar relays is the midget d-c relay T rls 6 (Fig. 4). It is outstanding for its electrical and mechanical ruggedness as well as for allowing a great many different combinations of coils and contact pileups. Despite its small size, contact pileups can be actuated up to an armature load of 400 gm. Communications type contact pileups (30 watts), power current contact pileups (100 watts), high-current contact

pileups (400 watts), and vacuum switches (max. 2 kw up to 2 kv) are available for equipping the relay.

The two switching states "armature attracted" and "armature released" usually correspond to the states where the energizing current is applied or removed. In control technology there are, however, many cases in which a relay is required to remain in its operated position even after energizing current has been removed. In such cases the T rls 6 may be provided with a latching feature which operates in response to a current pulse in the energizing coil. The contact pileup then remains mechanically latched until the arrival of the next pulse.

The relay is usually mounted on a shelf or directly on the chassis and then wired. For special applications, however, a plug-in type version in a dusttight case is available. D-c voltage is used for energization; feeding with a-c voltage is possible by using a full-wave rectifier.

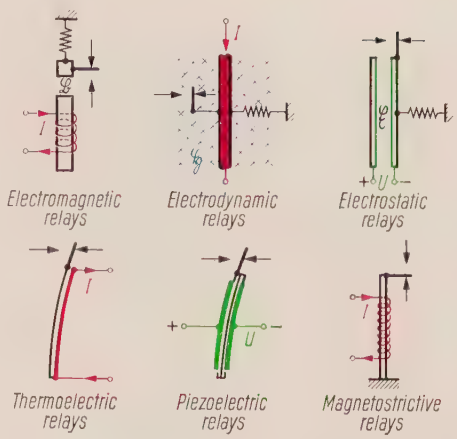


Fig. 2 Basic designs of electromagnetic relays

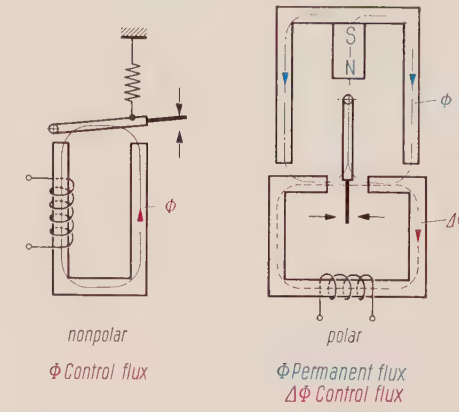


Fig. 3 Electromagnetic circuits

Large d-c relay

For higher sensitivity and more stringent requirements with respect to pull-in and drop-out delay, the large d-c relay T rls 159, like the midget d-c relay, may be provided with any of various contact pileups (up to 400 watts). Its precision with respect to pull-in and drop-out times make it particularly suitable for use in timing circuits.

One example that may be mentioned is its use in electric fence controllers. These are required to consume very little current (battery operation) and the pulses must be of exactly defined amplitude and repetition rate. Equipped with a vacuum switch, the T rls 159 satisfies these requirements. The vacuum switch was chosen because its contact operates in the vacuum practically free from arcing and is immune to atmospheric effects, while the switch itself is outstanding for its long life, absence of maintenance requirements, and extremely fast switching.

The T rls 159 is suitable for direct operation on up to 220 v d-c. For operation on a-c voltage it is necessary for a rectifier to be interposed.

A-c/d-c relay

In the case of the T rls 152, a wedge of insulating material attached to the armature moves between the spring contacts, thereby actuating them. The relay operates on d-c or a-c. If a-c is used, a rectifier is not required.

To prevent the armature from dropping away at zero crossovers of the a-c, the magnetic flux is divided into two partial fluxes offset by about 90 deg by placing a shorting ring over one half of the middle strap of the laminated magnet core. The relay can be screwed to an assembly plate.

Power relay

The T rls 38 power relay is particularly suitable for heavy-duty equipment. It has been manufactured with practically no design modifications over many years and has given excellent service in mining equipment. It operates on d-c or, if a rectifier is used, a-c as well.

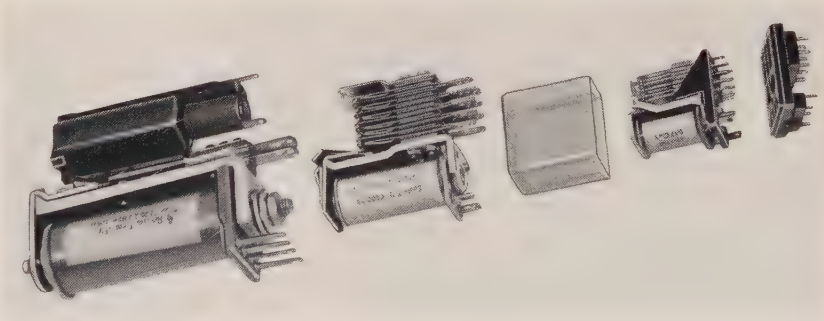


Fig. 4 Nonpolar relays: large d-c relay T rls 159 with vacuum switch, midget d-c relay T rls 6 and cradle relay T rls 154 with socket

Cradle relay

The T rls 154 cradle relay finds widespread application on account of its small size (34 mm × 24 mm × 19 mm). It can be either plugged in or soldered. If provided with a suitable socket, it can also be embodied in printed circuits.

The energizing coils are dimensioned for pickup powers of 35 mw and higher, and for voltages of less than 1 volt up to approx. 150 volts. The contact pileups can be varied to a great extent and equipped with contacts made of various metals. Signal current contact pileups can handle up to 30 watts and power current pileups up to 100 watts.

Like other communications components, the relays can be hermetically sealed to protect them from the ambient atmosphere. Hermetic sealing is of value, however, only if it is absolute. Even the slightest leakage such as incipient cracks in the glass lead-throughs are liable, in the event of large changes in temperature, to permit the ingress of outside air and moisture. This leads to the formation of what is termed a miniature climate that may disturb the functioning of the system. Great care must for this reason be devoted to manufacture and assembly. Hermetically sealed cradle relays are also available (T rls 162). The admissible temperature range lies between –40 and +80 °C.

Owing to their ability to withstand impact and vibration, all cradle relays – and the hermetically sealed version in particular – are suitable for use in all types of vehicles. They are also widely used wherever a great many relays have to be accommodated within a small space, such as in electronic computers and automation equipment. The factory output of these relays has already passed the 4 million mark.

Polarized electromagnetic relays

The motion of the armature of polarized relays is produced by the force resulting from the permanent flux, the control flux (also termed energizing flux) and, frequently, also the force of a bias spring. In contrast to nonpolar relays, the forces acting upon the armature thus depend not only on the control flux Φ_S but also in large measure on the permanent flux Φ_0. Assuming a permanent flux density B and a control flux density ΔB, the variation of the attracting force will be

$$\Delta P = C_2 B \Delta B$$

As the value of B can be chosen arbitrarily, polarized relays can be designed with greater sensitivity than nonpolar relays. C_2 denotes a constant depending on material and design.

The direction of motion of the armature (travel S; Fig. 5) depends on the polarity of the energizing current. The respective portion of the permanent flux (Φ_{01} or Φ_{02}) in one of the air gaps of the armature will accordingly be increased by the amount of the control flux Φ_S, while that in the other air gap will be reduced by the same amount. The bias spring has a characteristic in opposition to the permanent flux force F_D. It attempts, by way of its spring force F_F, to pull the armature into the middle position, whereas the permanent flux force F_D attempts to pull the armature to an end position. The characteristic of the relay can therefore be largely influenced with the spring.

With polarized relays a distinction is made between various armature adjustments that are dependent on the resulting force F_A, which is composed of the permanent flux force F_D, the spring force F_F and the control flux force F_S. In the case of a 2-position armature, $F_D > F_F$, thus causing the armature to remain in the position to which it has been brought by the last energizing current pulse. If the chosen spring force F_F is greater than the permanent flux force F_D, the armature will remain in the center position when the energizing coil is currentless. This results in what is termed a 3-position relay. If a mechanically or magnetically asymmetrical setting is chosen, the result is a biased 2-position relay. When the relay is in a deenergized state, the armature is always held in the same position and is not actuated until energizing current of the appropriate direction flows (Fig. 6).

Polarized relays (Fig. 7) are used wherever there is a requirement for high operating sensitivity, a current-directional feature, and where the coil is required to be capable of handling considerable overloads.

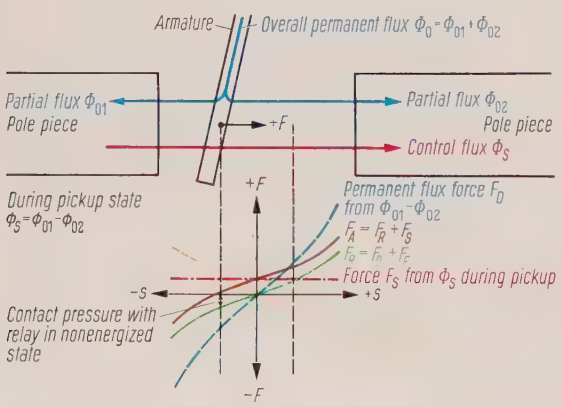


Fig. 5 Forces acting upon armature of a polarized 2-position relay

Polarized midget relays

The principal relays of this type are the midget relays T rls 63 to 69. One of their main features is the observance of extremely exact switching times for a vast quantity of operations. To avoid contact bounce as far as possible in the case of dynamic operation, the armature, which is suspended on a torsion spring, is fitted with a friction spring. During operation the friction springs

are displaced with respect to each other as a result of the armature impinging on the stationary mating contact, whereby the friction areas convert the bounce energy into frictional heat. Relays that are required to have extremely accurate pull-in and drop-out values in static functioning are provided with a rigid armature instead of a friction-spring armature. Polarized midget relays are normally fitted with one double-throw contact, but versions with 2-pole double-throw contacts are also made.

Polarized midget relays are primarily used in telegraph equipment, where the capability of the energizing coil to handle extremely high overloads is an advantage. In the case of faults, the applied power may permissibly rise to as much as 10,000 times the rated pickup excitation without any danger of the characteristics of the relay undergoing a change.

Polarized midget relays are also used in monitoring and measuring circuits, where their high sensitivity is once again an important factor. A special version serves as an input vibrator for very low switching powers in d-c voltage amplifiers (choppers). Under the type designation T rls 163 to 169, they are also available hermetically encapsulated.

These relays are used in their present form as standard relays for telegraph equipment all over the world.

Polarized miniature relays

The polarized miniature relays T rls 173 to 179 are designed as small hermetically encapsulated relays, that, however, do not meet the same high accuracy standards with respect to switching times as the polarized midget relays. Their small size and high sensitivity have secured them a wide range of application, especially as sensitive control relays.

Polarized subminiature relays

The smallest among the nonpolar relays is the cradle relay. For many applications, however, this relay is still too large. Miniaturization of the relay, on the other hand,

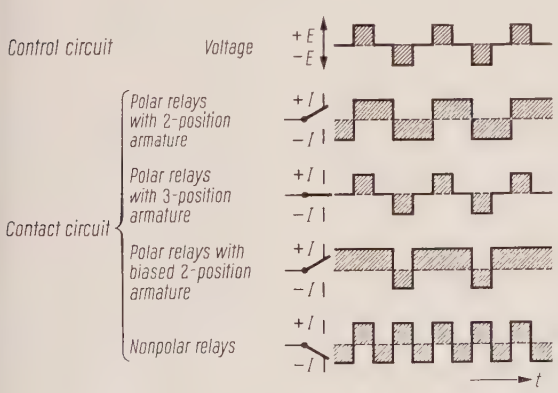


Fig. 6 Operating principle of differently adjusted relays

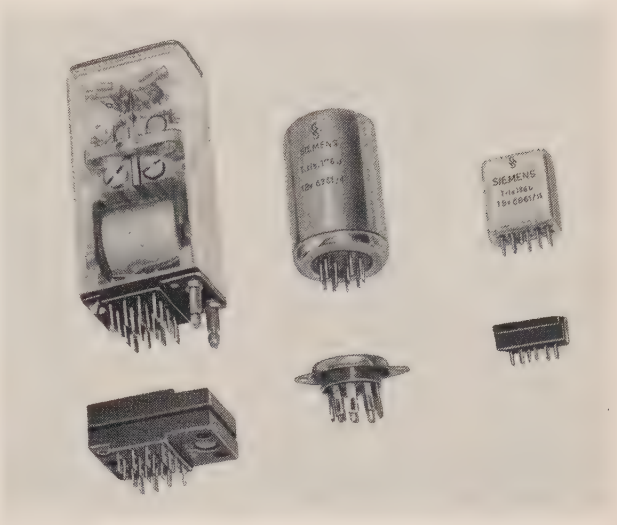


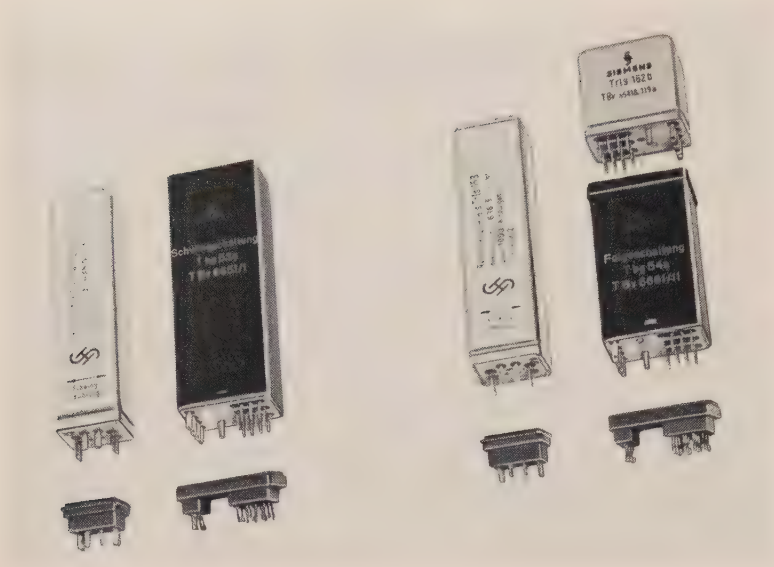
Fig. 7 Polarized relays: midget relay T rls 64, miniature relay T rls 176 and subminiature relay T rls 186

is possible only by sacrificing winding space which, together with the magnetic circuit, determines pickup sensitivity. Relays smaller than this are therefore advisably designed as polarized relays. Extra-small relays developed for such applications are the polarized subminiature relays T rls 186. For dimensions of 25 mm × 21 mm × 10 mm, they have a volume of only about 5 cm^3. They combine the advantages of the polarized system, e.g. high pickup sensitivity and overload-handling capability, with extraordinary small dimensions [1, 2].

Resonant reed relay transmitting assembly

For many communications applications it is desired to have a relay that operates to certain frequencies. The resonant reed relay T rls 153 a [3, 4] is here used. It operates on the polar principle. Armature and contact system oscillate with a low degree of damping and are very exactly tuned to a given mechanical characteristic frequency. When the frequency of the energizing a-c current corresponds with this characteristic frequency, the relay already operates to about 0.6 mva: the armature, designed as a tuned steel reed, begins to oscillate and, in its end position, closes a wire contact in step with the energizing frequency. The switching power for continuous operation amounts to about 0.75 watts. A specially developed coherence circuit with transistor amplifier T bg 54a can be added for conversion from intermittent to steady contact make and for power amplification. Cradle relays can be plugged to this unit as desired for use as switching relays.

The resonator T rls 153b is similar in design to the resonant reed relay [4]. In conjunction with the transistorized resonant circuit T bg 53a, the two units form a regenerative feedback generator with a power output of 2.5 mva; a power supply of 600 mw is required.



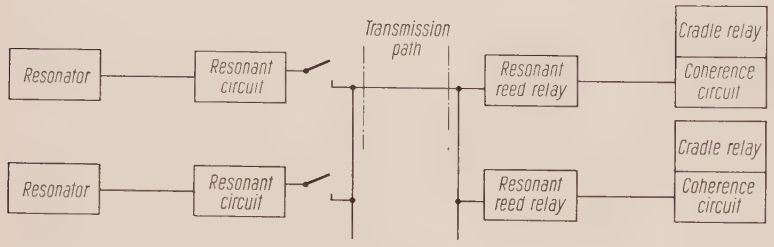


Fig. 8 Resonant reed relay transmitting assembly: resonator T rls 153b, resonant circuit T bg 53a, resonant reed relay T rls 153a and coherence circuit T bg 54a with cradle relay T rls 162

All units have a plug-type base and a dusttight cap; the resonant reed relay (receiving relay) is hermetically sealed. These components may be used to assemble a complete transmitting and receiving system in which up to 41 signaling channels can be accommodated for single-frequency transmission in the range from 350 to 950 cps with the rated frequencies spaced 15 cps apart.

Contact materials

The choice of a contact metal is of great importance. Thorough investigations have shown that no metal is suitable to the same extent for all operating conditions. Siemens & Halske have for this reason developed contact metals that are particularly suitable for the various applications encountered in telegraph and signaling technology.

The contact pileups can be provided with appropriate contact metals according to their application. The types of contact metal used must, however, be limited on the grounds of economy. The principal metals used are the following:

The most frequently used contact metal is silver. It exhibits excellent electrical and thermal conductivity and is moderately priced. Widely used for the relays made by Siemens & Halske, it has given decades of excellent service. It is particularly suitable for high switching currents with low switching voltages. The main drawback of silver is that it is prone to sulphidization and, in its pure state, is relatively soft.

Gold is extremely resistant to corrosion. However, pure gold is too soft for contacts and must therefore be alloyed with other metals. As the slightest variation in the constituents of the alloy may often have a considerable effect on the characteristics of the metal, great care must be devoted to its production. An alloy of this type is gold-nickel, which is as resistant to corrosion as gold and particularly suitable for voltages between 6 and 50 volts. For switching very low powers it is recommendable to use gold-platinum.

There are also a number of other multiple alloys containing gold which have given very good service in handling low-level powers and are used for special applications, but to enumerate them all would go beyond the scope of this paper.

As tungsten has a high melting point and great hardness, it can, given sufficient contact pressure and voltages above 12 v, handle relatively high powers. It is not, however, recommendable for all applications in tropical climates.

For polarized relays, preference is given to platinum as a base. It has a high melting point and excellent resistance to corrosion. The platinum-nickel alloy used for telegraph equipment is particularly suitable for switching the telegraph voltage of 60 volts. Owing to its restricted material migration and great hardness, it guarantees a long period of maintenance-free operation. A platinum-tungsten alloy has been developed for switching currents exceeding 0.5 amp.

In summary it may be said that the relay has lost none of its importance as the oldest component used in communications engineering, but has even found important applications in new fields such as that of automation.

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Corrosion Protection for Metallic Cable Sheaths

By Walter Jaeschke

While the life of most electrical apparatus, or at least of individual parts thereof, is naturally limited by wear etc., it is expected of a cable that it will give many years of maintenance-free operation.

In fact, the influences to which a cable is subjected with regard to its service life are exclusively of a detrimental nature, e.g.:

Exceeding of the load capacity
External mechanical damage
Corrosion of the metal sheath and reduction in the insulation strength owing to the subsequent ingress of water.

There is not much the cable manufacturer can undertake to combat the first two of these influences; however, damage due to corrosion of the sheath material can be averted with the aid of suitable protective measures and by using the type of cable best fitted for the purpose in question. Since the cable networks constitute an important part of the value of power supply and telecommunications systems – with 8 percent of the total investments, cables and wires represent one of the largest individual items in the German electrical industry – their corrosion protection is of no mean significance both from the technical and economical points of view. In the course of the last ten years or so, the problem of metal sheath corrosion has become more and more important due to the fact that increasing use is being made of light-alloy and steel sheaths.

The conditions connected with the corrosion of metallic cable sheaths are uncommon in that cables, unlike all other electrical apparatus, are exposed to the corrosive effects of the atmosphere, soil and water under the most varied and unfavourable conditions. Owing to their inaccessibility and the fact that they extend over great distances, there is generally no way of inspecting or servicing cables once they are laid. Owing to the heterogeneous nature of the surroundings the dangers of attack by corrosion are many and varied and can only in rare cases be treated as a whole. The analysing of soil samples, for instance, is only of doubtful value since it cannot possibly cover the whole length of the line and, in particular, since the composition of the soil may undergo substantial changes later as a result of subsequent earth deposits, building activities or the ingress of waste water. A statistical study of faults in cables due to corrosion has shown that phenomena which at first appear to be of secondary importance are often the decisive factor.

Thus it has happened that cables run in what was considered to be harmless sandy ground have been destroyed within a relatively short time as a result of the good soil ventilation, while they were not noticeably corroded in the marshy soil of the nearby moorland [1,2].

In addition to moisture in the ground, the following are the principal agents promoting corrosion in the metallic sheaths of buried cables:

Acidic constituents (acidic industrial waste water, acetic acid, humic acids)
Alkaline constituents (limestone, mortar)
High concentrations of salt (in the proximity of seawater, natural salt springs, salt mines, industrial waste water)
Large concentrations of bacteriological decomposition products (humus, liquid manure, fecal matter).

The "chemical" corrosion of cables takes place in the operating temperature range of the cables in damp environments and is almost without exception electrolytic in nature. The atoms of the sheath material assume positive charges and go into solution in the electrolyte in the form of ions, while at another part of the surroundings more noble, positively charged ions are freed, some becoming oxydized under the effect of the atmospheric oxygen (Fig. 1).

The conditions which cause corrosion of metallic cable sheaths are therefore as follows:

1. Ionic conductivity of the environment of the metal
2. Sufficient potential difference between the ions going into solution and those freed
3. Metallic circuit between the anodic and cathodic areas
4. The possibility for a current to flow without interruption due to the formation of a surface film or polarization.

Particularly dangerous for cables are unidirectional stray currents from d.c. networks and d.c. railways of the type which find their way into the ground via the rails used as return conductors. In the cases where these currents take the path of least resistance through cable sheaths (Fig. 2) the material of the sheaths is attacked by corrosion, particularly at points where the current leaves the cable. Alternating currents leaving the cable sheath have no corrosive effect as long as the ions discharged during one half cycle are kept stationary and

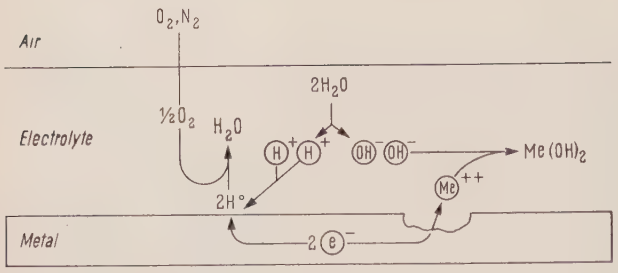


Fig. 1 Electrochemical corrosion of a bivalent metal

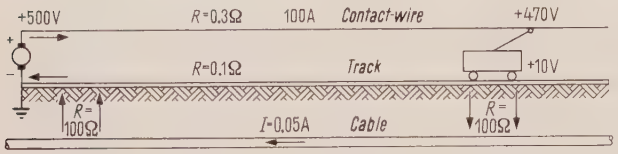


Fig. 2 Corrosion due to stray currents from d.c. electric railways

once more assume their original state during the next half cycle. Damage is only to be expected when a gas is produced at the electrodes as a result of very high current density – the limiting value is approximately 15 A dm^{-2} at 50 c/s. The limiting current density stated above far exceeds the current densities occurring in practice.

Sheath materials

At present, lead, aluminium, steel and copper are used as moisture-proof seals for cable core assemblies and in some cases also at the same time as neutral conductor.

For the last 70 years or so lead has been used extensively for cable sheaths and, in spite of its considerable disadvantages from a technical point of view, is still used predominantly today. Owing to its relatively high normal electrode potential of –0.12 V (referred to a normal hydrogen electrode), the formation of a high hydrogen overvoltage of about 1 V and the insolubility of many lead compounds which leads to the formation of protective surface films, lead is a metal which is to a high degree resistant to corrosion. Thus lead is resistant to neutral carbonated water; if, however, acids are present which dissolve the surface film, the lead will be affected. With lead, corrosion may affect a large area, take the form of pitting and may also be intercrystalline in nature. One particular manifestation of lead cable corrosion is the so-called "phenol corrosion" which generally begins under the bedding of the outer serving, is characterized by its attack on the grain boundaries and leads to the formation of crater-shaped holes and pin-point capillaries (Fig. 3).

According to Da Fano [3], phenols present in the outer cable servings act as a catalyst in the corrosion of the lead over the intermediate stage of lead phenolate to lead carbonate. However, it has never been proved that lead phenolate is present in "phenol-corroded" cables. More recent studies [4, 5, 6] have shown that the frequency of "phenol corrosion" is independent of the phenol content of the cable serving and that, particularly with cable servings originally free of phenols, the phenol content is increased by the bacteriological decomposition of the jute used as the serving. Under certain conditions phenols can even have an inhibiting effect on corrosion [18]. Damage to cables due to "phenol corrosion" has undergone no noticeable reduction, even although in the Thirties the basis of the asphalting compounds was changed for the most part from coal-tar to non-phenolic bitumen. It must therefore be assumed that "phenol corrosion" is caused by a coarsening of the grain of the lead and the effect of decomposition products of the outer cable serving [5, 8, 9].

In the case of stray current corrosion of lead, crater-shaped holes are generally formed; in addition to lead carbonate, such corrosion products as basic chlorides, neutral and basic lead sulphate and, with higher current densities, higher-valence lead oxides ($PbO_{1.87}$ and PbO_2) occur [10] (Fig. 4).

During the Second World War aluminium was used to a limited extent for cable sheaths and has come into more extensive use in the course of the last ten years or so. It has several advantages over lead, having a higher mechanical strength, being less affected by vibrations and having a higher conductivity. Aluminium is a very base metal and has a normal electrode potential of –1.7 V referred to the hydrogen electrode as zero. The excellent durability of aluminium in air which is at least periodically dry is due to the formation of a dense film of amorphous and partly hydrated aluminium oxide. In constantly damp environments at temperatures below +70 °C, however, this film becomes hydrated to porous aluminium III hydroxide (gibbsite) which no longer reveals any special protective qualities, with the result that, at a mean conductivity of approximately 500 micromhos cm^{-1}, corresponding to that of the ground, aluminium in damp environments becomes about 0.5 mm thinner annually. Aluminium III hydroxide is also almost without exception the sole corrosion product of aluminium so that, in most cases, no definite conclusions can be drawn on the cause of corrosion from the nature of the corrosion products and from the appearance of the damaged part. Aluminium is usually attacked locally; owing to the protective oxide film still present at parts, corrosion is confined to smaller zones. Corrosion is accelerated by metallic inclusions in the aluminium (e.g. iron and copper) and any unavoidable surface impurities caused by foreign metals from drawing dies and press tools.

Steel has also been used for about 10 years as sheath material. Its main advantage is its high mechanical strength. The corrosion conditions with steel are similar to those with aluminium and are also characterized by

a low potential (−0.44 V) and by the fact that there is no surface film. Corrosion takes place occasionally when the chlorine ion content of the environments is high. The main corrosion product is a loose mixture of hydrous iron III hydroxides.

Copper has only been in use for the last few years in the manufacture of cable sheaths. The decisive factors here are its mechanical strength, excellent corrosion resistance and high conductivity. With a potential of +0.35 V, copper is the most noble of the metals used for cable sheaths and thus has a high resistance to corrosion. It is attacked practically only by organic acids of high concentration (acetic acid – formation of verdigris) and the effects of stray currents.

Owing to the behaviour of the sheath materials described above with regard to corrosion, it is necessary to protect buried and submarine cables against corrosion.

An exception to this are communications cables with lead sheaths, provided, as is generally the case, they are run in concrete ducts within built-up areas. In this case corrosion protection can be omitted if the ground water level is sufficiently low and the soil is pervious and non-corrosive, provided that the ducts are well bituminized inside and drained. It is also advisable to provide bright lead-sheathed cables intended for running in tubular ducts with a coating of neutral paraffin during storage and transport periods, particularly in the case of sea transport, in order to prevent the formation of white-spotted carbonate layers. The experience gained by German cable manufacturers, however, shows that the practice of running unprotected cables in ducts based on conditions in Central Europe cannot simply be applied to tropical conditions.

All other buried and submarine cables require protection against corrosion. This protection must be mechanically strong enough to resist stresses during transport and laying or not to be damaged during any subsequent earthwork. Consequently, only relatively thick layers with a thickness exceeding 1 mm can be used. With armoured cables, the corrosion protection may also have the task of acting as a cushion between the sheath and the armouring and thus compensating the pressure of the latter at the edges. The corrosion protection still used today in most cases for lead-sheathed cables consists of wrapped layers of plastic tapes with a supporting base of cellulose in the form of paper, fabric or jute (Fig. 5).

The fibres are always pre-pregnated to obtain better bonding of the compounds. Both coal-tar products as well as native rock asphalts and mineral oil bitumens are used as compounds. In order to permit laying of the cables at low temperatures, the compounds employed should have as low a breaking point as possible and, to prevent dripping at high ambient temperatures, as high a softening point as possible. Since these requirements are considerably better met by mineral oil bitumens, the role played by coal-tar compounds has become smaller and smaller; to a certain extent, this change was also accelerated by the fear of phenol corrosion. By adding high-molecular polymerisates, the physical properties of coal-tar products can be substantially improved so that they have been able to regain a small part of the field of application, particularly with steel-sheathed cables. In order to prevent the individual cable turns from adhering to the drum, the compound over the last fibre layer is made somewhat harder and provided with a coating of chalk paste. Owing to the formation of acidic decomposition products caused by decay of the cellulose substances, only sodium cellulose paper if possible should be used directly over the metal sheath and untreated fibres such as jute should be avoided. Such protection, composed of bitumen and cellulose, has one substantial disadvantage: Even in the impregnated state, the cellulose fillers absorb in a damp environment about 60 percent water – referred to the dry fibrous material – and this causes the protection to swell and become permeable to water and ions after some time. This can be seen in the fact

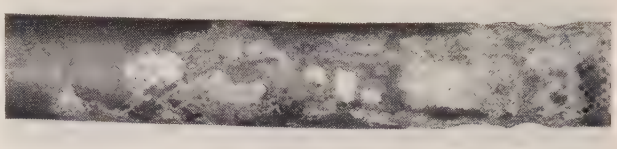


Fig. 3 Lead sheath destroyed by so-called "phenol corrosion"

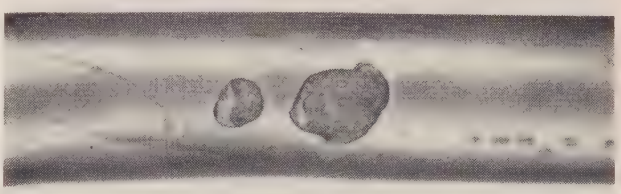
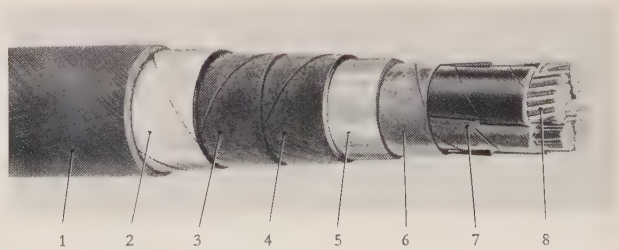


Fig. 4 Stray current corrosion of lead (under damaged corrosion protection)



1 Impregnated jute in compound
2 Steel-tape armouring
3 Bituminized paper in compound
4 Bitumen compound
5 Lead sheath
6 Belt insulation
7 Core insulation
8 Conductor

Fig. 5 Normal corrosion protection for armoured lead-sheathed cables

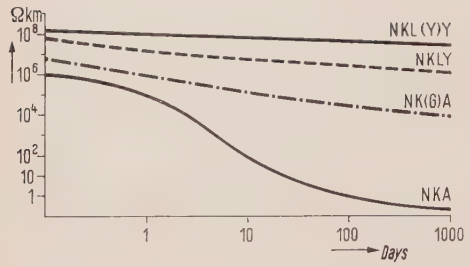


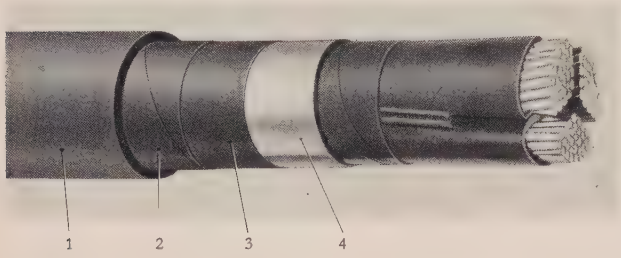
Fig. 6 Insulation resistance of various types of corrosion protection after suspension in water (temperature 20 °C)

that the insulation resistance, which is tens of thousands of ohm-km when the cable leaves the factory, drops after a few weeks in damp soil to values of about 1 ohm-km (Fig. 6). This feature, which at first sight may seem highly undesirable, is welcome not only in power supply networks, but also in communications networks, in that the cable sheaths of the generally extensive cable networks can also be utilized to improve the earthing conditions. Efforts to replace fibrous materials composed of cellulose by materials which do not swell and are fungi resistant have so far been unsuccessful since organic exchange materials (man-made fibres) are too expensive and inorganic materials (glass fibres) are mechanically unsatisfactory and difficult to process.

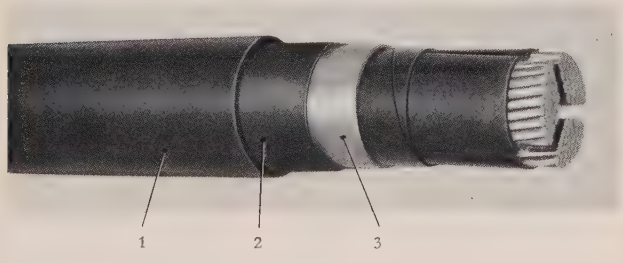
In spite of the reduction in the insulation resistance, however, lead sheaths are adequately protected in normal environments, apparently by a thin film of bitumen remaining on the metal sheath, and the protective surface layer already mentioned. However, in aggressive soil this protection is not reliable and breaks down completely when stressed with d.c. stray currents.

For these cases and for all aluminium-sheathed and steel-sheathed cables it is necessary to include in the corrosion protection at least one water and ion barrier layer in the special form used for the last 35 years with vulcanized soft rubber (sandwich construction). The type of barrier layer has no influence on the effectiveness of the corrosion protection. The only provision is that the barrier layer should have a sufficiently high insulation resistance even in damp environments and lie so close on the metal sheath or be bonded so close to it that seeping water or water which has ingressed in any other way cannot form pockets and undermine the layer. Wrapped tapes of vulcanized rubber have the advantage that they retain a residual mechanical tension independent of the initial spinning tension and cannot lift when bending stresses are applied. Properly wrapped tapes on a polyisobutylene basis, which cannot be vulcanized, bond together at the lapping joints and are at present probably the best solution. It is also possible to employ thin films of PVC or polyester. In order to provide the tapes with protection against mechanical damage, a normal asphalted jute coating is necessary (Fig. 7*a*).

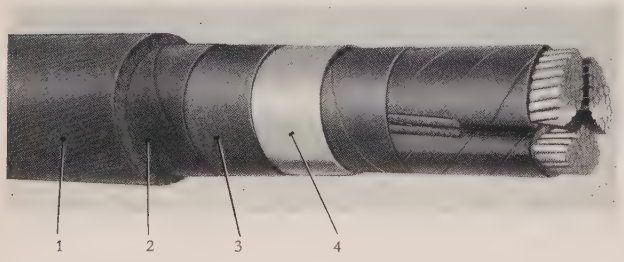
In addition to the wrapping method described, insulating and ion barrier layers can also be applied as seamless plastic sheaths with the aid of screw extruders. Both PVC (polyvinyl chloride) in medium-hard form and PET (polyethylene) can be used for this. In suitable compositions both materials are about equal from the mechanical and technological points of view. As with the wrapped layers, screw-extruded sheaths require that the plastic sheath be closely bonded with the metal sheath. The fact that plastic sheaths at first came into disrepute with some brands of cables was due entirely to water seeping in between the metallic and plastic sheaths as a result of defects in the plastic sheath or improper preparation of the cable ends, working its way along the cable and thus giving rise to extensive damage through corrosion. Since sheaths manufactured on screw extruders require no external mechanical protection if their wall thicknesses are suitably dimensioned, such cables have a smooth, clean surface and, unlike those with a wrapped



a NKL(G)A
1 Jute in compound
2 Soft rubber tape
3 Special compound
4 Aluminium sheath



b NKLY
1 PROTODUR* sheath
2 Special compound
3 Aluminium sheath



c NKL(Y)Y
1 PROTODUR sheath
2 Plastic tape
3 Special compound
4 Aluminium sheath

Fig. 7 Corrosion protection for aluminium-sheathed cables

* Trade-mark

protective layer, can also be drawn into tubes. They are also completely resistant to fungi and, where PVC compounds are used for the sheaths, are inflammable (Fig. 7*b*).

Almost ideal reliability is offered by a combination of the wrapping and screw-extruder techniques, e.g. applying a seamless sheath of PVC over a wrapping of polyisobutylene tape (Fig. 7*c*).

Such types of corrosion protection composed of insulating layers have, when new, an insulation resistance of over 10 megohms per km. This value actually drops to 10^2 ohms within a few years due to moisture absorption but even then is still high enough to preclude damage to the cable sheaths by corrosion. With direct-current loading, the stray currents flowing are so small that no corrosive effect can be observed on the sheath materials (see Fig. 6). In addition, the sheaths are resistant to all chemical substances in soil and water and their application is limited in neither of the two directions.

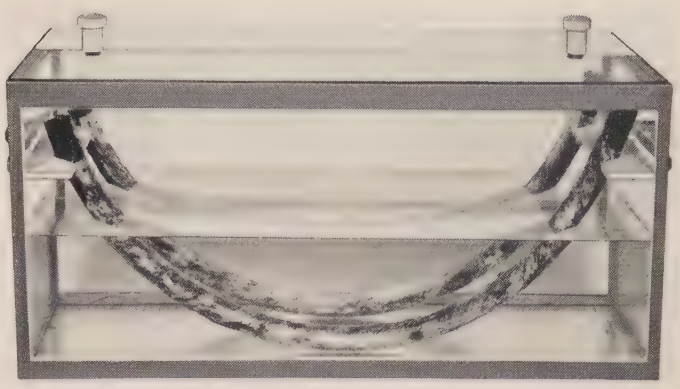


Fig. 9 Testing the corrosion protection in a tank

Cathodic protection

The potentialities of cathodic protection in cable installations cannot yet be definitely foreseen; the experience so far gained in this field is too confined to be able to offer a comprehensive survey. With cathodic protection the potential of the metal parts to be protected is lowered by short-circuiting them with auxiliary anodes of base metal (mostly magnesium) or by applying an external source of d.c. voltage via otherwise inactive anodes (graphite in coke back-fill) until the formation of cations from the metal ceases (Fig. 8). The maximum difference in potential required is about 1 to 1.5 V. The protective currents thus formed are governed by the conductivity of the surroundings, the type of ions present and the eventual formation of a protective film; they lie between approximately 1 to 100 mA per square metre of surface to be protected.

When the protective current flows, the cations present in the environment, particularly alkaline earth ions and alkali ions, are attracted to the protected surfaces where they are discharged; after the ions are discharged the corresponding alkaline hydroxides are formed. Cathodic protection therefore finds valuable application in those cases where, as a result of the cable design, a potential can be formed over the entire surface and where the metals to be protected are unaffected by alkalies, e.g. particularly with steel constructions which have no pronounced concave or screened surfaces. This also includes cables with corrugated steel sheaths and steel pipe cables. Cathodic protection is also possible for unarmoured lead-sheathed and copper-sheathed cables. Owing to the fact that both these metals are sensitive to concentrated alkalies, however, care should be taken that the current densities, and consequently the alkalinity, of the environments do not become too high. Cathodic protection is unsuitable for armoured cables since the surface of the metallic sheath is screened by the armouring and no protective potentials can therefore be formed. Aluminium can also not be protected in this way since even small alkaline concentrations have a destructive effect.

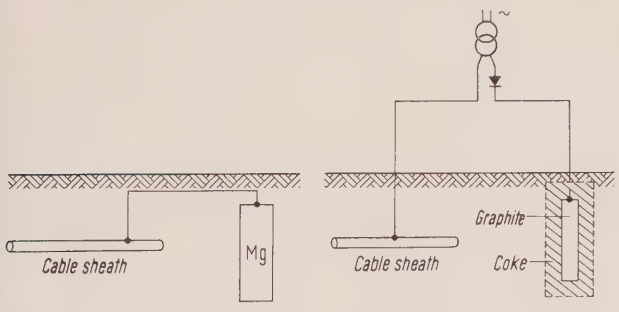


Fig. 8 Cathodic protection of cable sheaths

Corrosion protection tests

It is no easy matter to test the effectiveness of the various types of corrosion. The service life demanded of a cable is approximately 30 to 50 years. In view of the absence of simple time-cutting methods such as the exponential method of increasing the test temperature, a testing method, however, must provide results capable of extrapolation within a much shorter period. When making tests one has to rely on obtaining a linear time lapse by reducing the layer thickness to a limited extent, by increasing the concentration of corrosive agents and by applying d.c. voltages. Consequently, corrosion tests still require many years before they reach a stage of completion so that, in the development of the various types of corrosion protection, experience already available and model tests have to be resorted to.

It is also not possible to take into account all the conditions encountered in the field and results obtained in the laboratory still always have to be confirmed in practice.

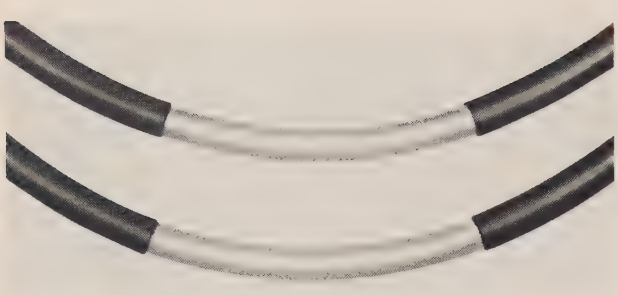


Fig. 10 Protected aluminium-sheathed cables of the type shown in Fig. 7*c* after being tested for a year in a tank containing 5 percent acetic acid

For laboratory tests it has proved advisable to subject the samples of cable first of all to bending stresses in accordance with VDE (Association of German Electrical Engineers) Specifications and then to suspend them in tanks filled with corrosive substances and observe any changes which occur (Fig. 9). In the case of such protection with insulating layers, the test can be intensified by applying a d.c. voltage of about 6 to 15 V. Incipient corrosion can be detected particularly early by measuring the leakage currents.

Available data

The experience gained so far, particularly from statistics made by German Electricity Supply Undertakings and the Post Office, shows that the corrosion protection consisting of bituminized fibres normally used for lead-sheathed cables is adequate in fairly neutral soil and in over 20 metres of water. The relatively small number of faults recorded did not seem to justify additional expenditure. The normal type of protection often breaks down in very corrosive ground and as a result of stray currents. In these cases, and in every instance where aluminium-sheathed or steel-sheathed cables are used, a protective barrier impervious to water and ions and consisting of a wrapped tape or an extruded seamless sheath or a combination of both is necessary. Such types of corrosion protection have proved reliable under all possible conditions (Fig. 10); the diminishing number of cases where faults occur due to corrosion can, without exception, be traced back to defects in the protective sheath.

The combined system with compound filling under the wrapping affords protection for the metallic sheath, even if there should be defective spots in one of the two protective coverings, and provides the greatest degree of reliability against all types of corrosion. For aluminium sheaths this two-layer protection has become standard and can be used equally well for cables buried in the earth, installed in ducts or run on bridges.

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Dial Office Technology and Local Network Configurations

By Alois Brandstetter and Helmut Wahl

Already 84% of all the telephone installations in the world are connected to dial offices. The respective subscriber lines are grouped to form various types of individual or interconnected dial offices, depending on the number of subscribers and the size and economic structure of the local network. A close economic tie-up will here be seen to exist between the dial office technique and the configuration of the network of inter-office trunks. If network configuration and the office numbering plan are coordinated, quite simple dial systems can be used [1]. Where there is no such coordination it is necessary to use dial systems that satisfy the given routing requirements [2, 3, 4].

To arrive at the optimum overall solution for any given case, it is usually necessary during the course of the

routine planning work to make an economic analysis that permits an appraisal of the various potentialities. The present paper first considers the relative economy of various types of dial offices and then the basic potentialities available in designing the inter-office trunking network.

Economy of various types of dial offices in limited network areas

As the cost of the subscriber line network usually comes to more than half the overall cost of a telephone system, dial offices should be located as close as possible to points of maximum subscriber density. This involves the "decentralization" of dial office equipment. For small groups of subscribers located relatively far from their dial office, copper can be saved through the use of out-of-area switching equipment such as two-party (shared service) lines and line concentrators. For large groups of subscribers certain sections of a parent dial office can be located in their vicinity; such decentralized sections are termed sub-offices [5]. If the overall traffic originating in the area of a sub-office is directed from the sub-office to the parent office, the sub-office is said to be nondiscriminating. Traffic between two subscribers on the same sub-office (intra-office traffic) is therefore conducted over two line paths between the sub-office and the parent office. If intra-office traffic is processed within the sub-office, however, the latter is said to be discriminating. The trunkgroup leading to the parent office then carries only the traffic with other offices.

Investigations have been made to determine the optimum solution for a new dial office under various given conditions. Fig. 1 shows, by way of example, the economy limits of three possible types of office for 200, 400 and 800 line units (LU) respectively. A local network with a 2,000-line parent office is here assumed. It is further assumed that the new office has a two-stage linefinder (*LF*) arrangement if designed as a nondiscriminating sub-office, or a single-stage *LF* arrangement if designed as a parent office or discriminating sub-office. 100-pt EMD switches are provided in all three cases. A traffic intensity of 4 erl per 100 subscribers is assumed for incoming and outgoing traffic, which is composed to 75% of local calls and to 25% of service and long-distance calls. Incoming traffic is assumed to arrive at the new office over one trunkgroup.

The diagrams show the nondiscriminating sub-office to be the optimum solution in cases where intra-office traffic represents up to about 20% of the overall traffic. The two intra-office paths do not yet involve any economic disadvantage; the saving in trunks realized through merging the overall traffic in the two-stage *LF* arrangement is still the major factor.

In the case of heavy intra-office traffic, the optimum solution is a parent office if the new office and the existing office are located relatively close together, or a discriminating sub-office if the new office and the existing office are located farther apart. Advantages in the case of the discriminating sub-office are, in the given example, the combination of the discriminator with a group selector to form a discriminating group selector (*DGS*), and the improved occupancy secured for the outgoing inter-office trunkgroup through higher accessibility at the *DGS*. Particularly with large offices, such advantages are primary factors if the conservation of long inter-office trunks is sufficiently great.

If some of these assumptions are changed, the economy limits for the individual types of office may be very different. In Fig. 2 these limits are indicated for a new 400-line office in the assumption that it is designed as a parent office or a discriminating sub-office operating with 200-pt *LF* arranged in a single stage. As a result, the economy limit of the nondiscriminating sub-office changes as indicated in Fig. 2.

For large local networks the optimum type of office can generally be determined from an economic analysis which makes allowance for the given quantity, size and location of the offices in the local network, traffic intensities, splitting of traffic, etc. As in the foregoing investigations, an analysis of this type should cover the overall outlay

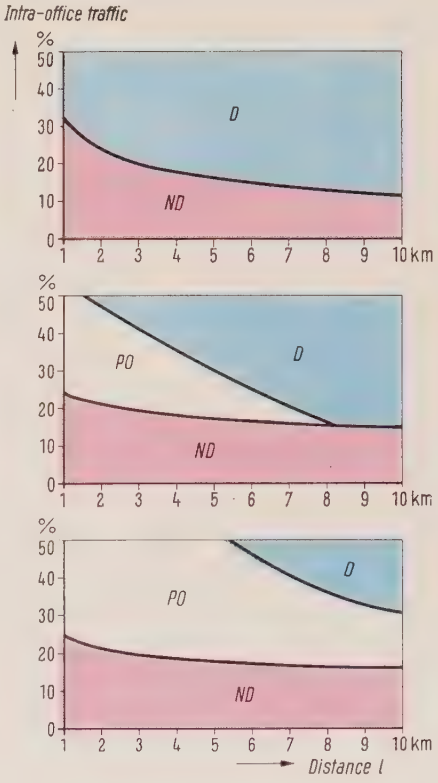


Fig. 1 Economy limits of a new dial office with 200 (top), 400 (center) and 800 (bottom) line units when adapted as nondiscriminating sub-office (*ND*), parent office (*PO*) and discriminating sub-office (*D*). *l* indicates the distance of the new dial office from the already existing parent office with 2,000 line units

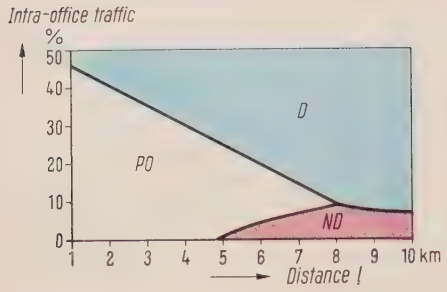


Fig. 2 Economy limits of a new dial office with 400 line units. The linefinder trunking diagram has been modified as compared with that shown in Fig. 1

for the new office, the additional outlay for already existing offices, and the additional outlay for inter-office trunks.

Configuration of inter-office trunking network

For reasons of economy and trunking it is usually inadvisible to assign more than 10,000 subscribers to a single dial office. Subscribers on a sub-office are usually allocated call numbers from the numbering group of the parent office. The parent office and its sub-offices thus represent a numbering unit with, say, up to 10,000 LU. Each such group of offices forming a 10,000-line numbering unit will, for the purpose of this paper, henceforth be referred to as an "exchange". In the downtown district of large cities or in other districts of high subscriber density it may be of economic advantage to locate several exchanges together in the same building.

A local area with several exchanges should basically be provided with

a) further switching stages at each exchange (in addition to the switching stages for subscriber discrimination) for the selection of intra-office and inter-office routes;
b) inter-office trunks.

In order that an optimum overall solution may be arrived at, the inter-office trunking network, the grouping of switches, and switch control requirements should here be considered as a whole.

The inter-office trunking network is usually so designed that certain correlations existing between numbering and network configuration are observed. This results in an essential simplification of the dial system.

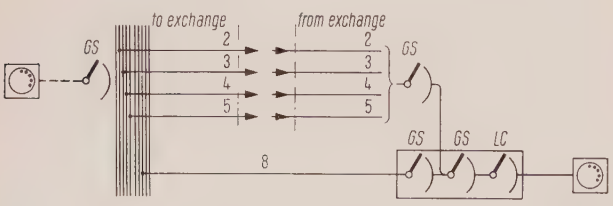


Fig. 3 Trunking diagram in exchange 8 of a local exchange network with 5 exchanges (meshed network)

An arbitrary choice of numbering and network configuration does not appear advisable because it would make the dial system considerably more complex; practical reasons (e.g. limitation of quantity of line sections for reasons of attenuation) would also prevent any benefit from being derived from the expected flexibility in planning.

The grouping of switches depends on the network configuration, the type of switches used, and the method of switch control. At all exchanges it must be possible to select at least as many routes as may be required by reason of the respective network configuration.

The switch control requirements depend on the type of routing performed within the exchange and sometimes also at following exchanges. It may be necessary to store and interpret one or more digits, or even to add or absorb digits. It is a general rule that the traffic concentration in common connecting paths, i.e. the occupancy of the network, becomes increasingly important as the number of exchanges increases, and that the switch control requirements increase at the same time.

Local networks with up to 10 exchanges

For local networks with only one or two exchanges the situation is so simple that no special considerations are necessary with respect to the inter-office trunks. In local networks with from 3 to 10 exchanges (5-digit directory numbers) it is usual for all the exchanges to be directly interconnected. This type of network presents the advantages of the shortest possible line paths for inter-office traffic and direct trunks between originating exchange and wanted exchange (no transit offices).

The grouping of switches at the exchanges is extremely simple; up to 10 required routes are usually available at a switching stage. This means that the switch control principle does not have to meet any particular requirements with respect to route selection.

Fig. 3 shows an example for the grouping of switches in a local network with five exchanges. Here and in the examples that follow the routes 1 and 0 are basically assigned to service calls and long-distance calls.

The traffic originating at an exchange can also be routed to the wanted exchange through another exchange that is favorably located from the traffic engineering aspect. This permits a saving in inter-office trunks but at the same time means increased requirements with respect to the route selection technique and quite possibly longer line paths for certain calls.

Local networks with up to 100 exchanges

In local networks of this size (with 6-digit directory numbers), various basic inter-office trunking network configurations and certain enlargements thereof are used with a view to concentrating the streams of traffic [6,7].

The magnitude of concentration so achieved, however, is not by itself a criterion for the economy of the network configuration, for no notable further saving in trunks can be achieved from a certain size of trunkgroup upwards. It is therefore always necessary to consider the overall economy (including the required technical equipment).

Meshed networks offer, in such local networks, the same advantages as in small local networks. Owing to the large number of exchanges, however, the outgoing inter-office traffic is split into a correspondingly large number of streams, which will therefore be small.

In a local area with 80 exchanges, for instance, each exchange requires 79 trunkgroups for outgoing and 79 trunkgroups for incoming traffic. Given an even distribution of traffic and a local traffic intensity of 400 erl per exchange, only 5 erl will be carried in each trunkgroup. As the distribution of traffic is, in practice, not even on account of the different interest factors [7], many trunkgroups will be found to carry even less traffic. Assuming 2.5 erl per trunkgroup, the line occupancy drops to 21 min in the busy hour, while with 1.5 erl it drops to 15 min.

The grouping of switches in the exchanges of a meshed network should permit a choice among a relatively large number of routes. Each exchange is accordingly assigned a corresponding quantity of switchgroups for route discrimination. As no special requirements here exist with respect to switch control, it is possible to use switches which, say, can be directly pulsed.

The office codes of the various exchanges of the local network can be allocated arbitrarily.

Local junction exchanges for incoming traffic permit a traffic concentration that will lead to improved trunk occupancy in almost all trunkgroups.

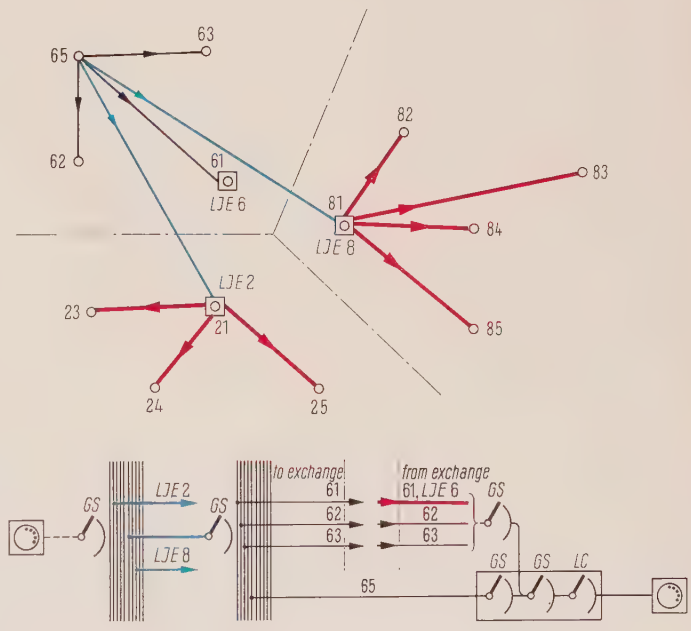
The entire local area is subdivided into various districts and a meshed network established only within each district. The traffic between the various districts flows over common trunkgroups. The exchanges that collect this traffic are termed local junction exchanges or tandem exchanges. If the local junction exchange (*LJE*) is inserted in the connection in such a way that the call is routed through it to the wanted exchange, the *LJE*'s will handle the traffic that flows into their area: *LJE*'s for incoming traffic.

Fig. 4 shows a section of a local network with the trunkgroups that accept the traffic outgoing from exchange 65; the grouping of the switches at exchange 65 is shown in the bottom diagram.

If a local area contains, say, 80 exchanges (distributed among 8 *LJE*'s), each exchange requires 16 trunkgroups for outgoing traffic and 10 trunkgroups for incoming traffic. The traffic concentration achieved on trunkgroups to the *LJE*'s of other areas is in this way increased up to 10 times and, on the incoming trunkgroups from the *KJE* of the local area, up to 70 times. The advantage of this improved trunk occupancy is accompanied by the drawback that many calls are not directed over the shortest route but through the *LJE* over two line sections (higher attenuation). In order to shorten the connecting paths and reduce attenuation it may therefore be advisable to accommodate the switches of the *LJE* in different, suitably located exchanges (establishment of sub-*LJE*).

The office codes for the various exchanges can be allocated arbitrarily within each *LJE* area.

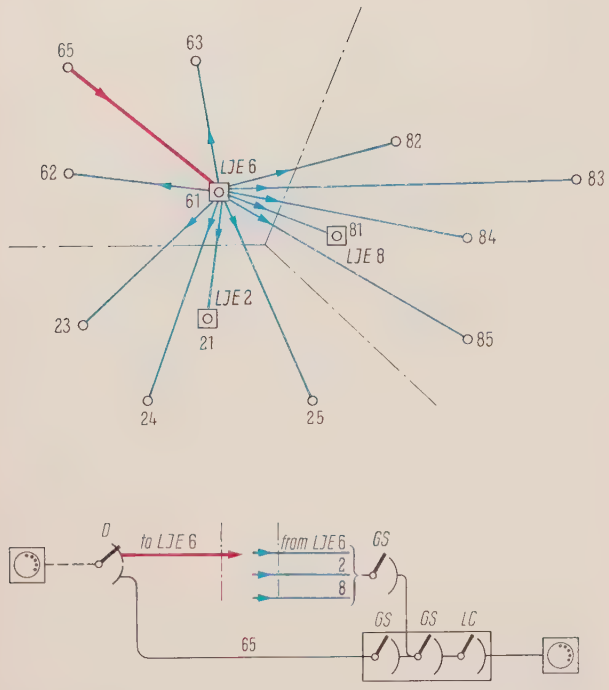
It is a particular advantage of this network configuration that a concentration of traffic can be realized without additional demands arising with respect to switch control. As all switches can be directly pulsed, an extraordinarily economic overall solution will be available, especially in the case of direct-pulsing systems. This network configuration is based on that of the large local networks of the West German Post and other telephone administrations.



Trunkgroup without traffic concentration
Trunkgroup with traffic concentration increased up to 10 times
Trunkgroup with traffic concentration increased up to 70 times
(in Figs. 5 and 6 up to 100 times)

LJE Local junction exchange *GS* Group selector *LC* Line connector

Fig. 4 Section of a local network with local junction exchanges for incoming traffic.
Shown at the bottom is the trunking diagram of exchange 65



D Discriminator

Fig. 5 Section of a local network with local junction exchanges for outgoing traffic.
Shown at the bottom is the trunking diagram of exchange 65

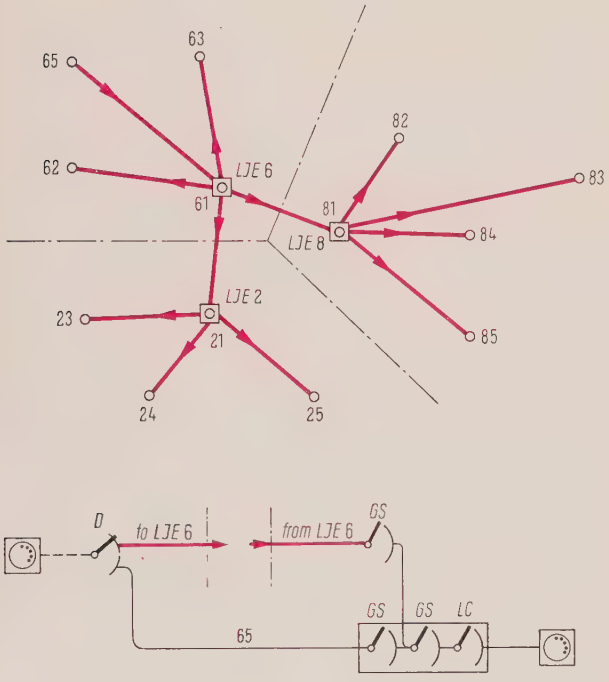


Fig. 6 Section of a local network with local junction exchanges for outgoing and incoming traffic.
Shown at the bottom is the trunking diagram of exchange 65

Local junction exchanges for outgoing traffic permit a concentration of traffic by the fact that local calls are routed through the *LJE* of the local area. Fig. 5 shows the inter-office trunks for traffic outgoing from exchange 65 and also the trunking diagram of exchange 65.

In a local area with 80 exchanges, each exchange requires one trunkgroup for outgoing traffic and eight trunkgroups for incoming traffic. The traffic concentration realized on the trunkgroup to the *LJE* of the local area is here increased up to 79 times and that on the incoming trunkgroups up to 10 times. This advantage, however, is likewise accompanied by the drawback of calls being established over two line sections.

Additional switch control requirements arise in local networks of this type because the first digits have to be used for operating the switches in the *LJE*. This generally means that discriminators (*D*) or local route selectors (*RS*) have to be provided at the originating exchanges [2]. For calls within the local junction exchange area it is also possible to provide direct trunkgroups insofar as economic advantages can in this way be gained.

The office codes for the various exchanges can be allocated arbitrarily within the local area.

Local junction exchanges for outgoing and incoming traffic permit an even greater concentration of traffic due to the traffic in other *LJE* areas being directed through both the local *LJE* and the *LJE* of the other area (Fig. 6).

In a local area with 80 exchanges, each exchange requires one trunkgroup for outgoing traffic and one trunkgroup for incoming traffic. The traffic concentration achieved on trunkgroups between the exchange and the *LJE* is in this way increased up to 79 times and that on trunkgroups between the *LJE*'s up to 100 times.

This advantage is accompanied by the drawback that all calls between the exchanges belonging to different *LJE* areas have to be directed through two *LJE*'s and hence over three line sections (increased attenuation)*. Moreover, additional switch control requirements arise the same as in local networks with *LJE*'s for outgoing traffic.

The numbering within the various *LJE* areas is arbitrary.

Composite network configurations resulting from the combination of the basic configurations already described can be adapted to the given local conditions.

The dial systems in the exchanges must here, as a basic rule, effect route discrimination in correspondence with the composite network. The EMD switch technique forms

* These remarks apply to local inter-office traffic. For long-distance traffic it is common practice to use a special network between the local exchanges and the long-distance exchange for reasons of attenuation.

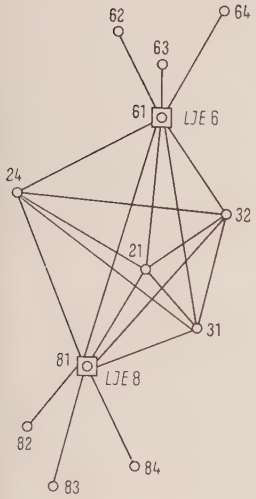


Fig. 7 Composite local network consisting of a meshed network and two radial networks with local junction exchanges

a particularly suitable basis for such dial systems. It allows flexible adaptation to all local conditions and, through the stagewise expansion of the basic system, offers an economic solution to all problems [1 to 4].

In a long local network, for instance, a meshed network can be used for traffic between downtown exchanges, whereas inter-office traffic between exchanges farther out runs through *LJE*'s (Fig. 7). This has the advantage that the heavy downtown traffic always reaches the wanted exchange by the shortest path, whereas the small streams of traffic to exchanges located farther out are merged at the respective *LJE*. The local network of Greater Buenos Aires, with its sometimes 7-digit directory numbers, is an example of a composite network [8].

If long indirect routes develop for individual connecting paths in cases where the network configurations we have described are used, and if a large portion of the traffic flows over these indirect routes (e.g. through one or two *LJE*'s), it is possible to expand the basic network so as to save additional trunks for such traffic. This, along with considerations of reliability, presents a requirement at certain exchanges for high-usage inter-office trunks and for the accessibility of not only one but several paths for the establishment of the connection.

High-usage trunks are particularly economic if they accept the major portion (e.g. 70 to 80 %) of the traffic, while the remainder is carried by the basic network. This method secures the satisfactory occupancy of the high-usage trunks and the basic network, but it also imposes more exacting switch control requirements. Digits have to be stored and interpreted for the selection of the high-usage path, and, if high-usage trunks are found occupied, the call must be able to overflow to the basic network. If high-usage paths are used it is generally necessary for certain digits to be absorbed, while if the basic network is used certain digits have to be added.

Fig. 8 shows part of a local network with various additional traffic facilities. Owing to the heavy traffic from exchange 55 to exchange 46, high-usage trunks have been provided in addition to the basic network. For the traffic to exchange 46, three paths are available, viz.:

the high-usage trunks to exchange 46 (no digits to be added),
the high-usage trunks to *LJE* 4 (one digit to be added),
the final path to local *LJE* 5 (two digits to be added).

Traffic to the *LJE* areas 3 and 8 is directed from the outset to the trunkgroup leading to *LJE* 5 on account of the small amount of traffic flowing into those areas.

For switching duties such as this, the EMD system M – a functional dial system operating with a straight grading and simple control devices – is particularly suitable [3, 4]. The required storage and conversion routines can be performed jointly by the pulse controllers (*PC*) and control sets (*CS*) of the local route selectors (*LRS*).

Local networks with up to 1,000 exchanges

In local areas such as this (with 7-digit directory numbers) it is not customary to use a fully meshed network because this would mean splitting up the traffic unduly.

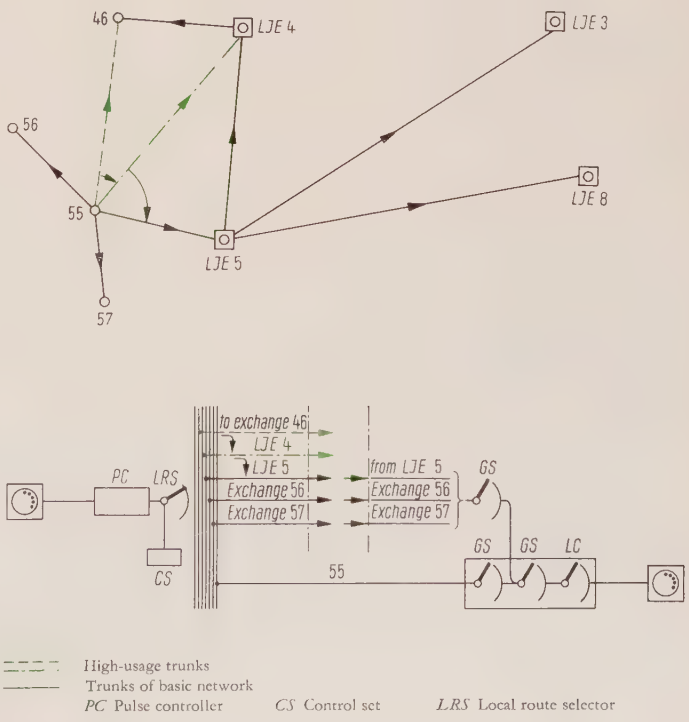
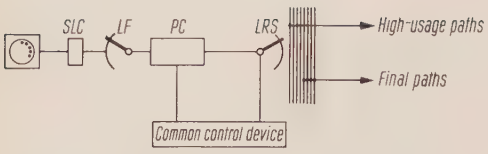


Fig. 8 Section of a local network with high-usage trunks. Shown at the bottom is the trunking diagram of exchange 55



SLC Subscriber line circuit *LF* Linefinder

Fig. 9 Control of local route selectors by common control devices

An economic network configuration is here arrived at by suitably reinforcing a basic *LJE* network with high-usage trunks.

In addition to routing over high-usage and final paths, local calls may here have to be zoned at the originating exchange. An economic solution [8] is offered in such cases by the EMD system M with centralized control devices installed preceding the local route selectors (Fig. 9). This technique makes it possible to satisfy all types of extra requirements in local networks with respect to routing and zoning.

The foregoing study points up the close relationship between network configuration and dial system technique in local telephone networks of different types and sizes. All problems encountered in planning local networks can be overcome with the EMD technique, which offers favorable solutions from the standpoints of both technology and economy.

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Digital Position Control for the Shear Gauge of a Light-section Rolling Mill

By Friedrich Fröhr and Reinhold Schmidt

After rolling out the light-section steel – rods, square sections and structural material – it must be cut to the desired commercial lengths with strict adherence to definite tolerances. Major deviations from the specified dimensions would naturally result in a high degree of cutting waste and losses.

The roughly cut light sections are allowed to run on a roller table against an adjustable gauge head and the entire bundle is cut, for instance, with a cold shear. During this process it is necessary that the position of the gauge with respect to the shear can be detected, indicated and adjusted by simple means with the desired accuracy and within the tolerance range.

Control methods used so far

For the position control of the shear gauge, predominant use is still being made at present either of dial indicators, which indicate analogously the distance from the shear with the aid of pointers, or mechanical counters with digital length indication. Between the gauge and the indicating device, therefore, are located mechanical or electrical transmission elements, such as gears, synchros etc.

On considering such devices, it is not difficult to see the limits of their accuracy: pointer readings are always subject to errors, depending on the angle from which the scale is viewed. Both mechanical and electrical counting mechanisms are restricted in their speed. At a given adjustment speed, therefore, there is a limit to the permissible distance unit which can be selected. The transmission elements are also a source of error and the angular congruity between individual synchros (transmitter and receiver) is not perfect. In interposed gears or other mechanical transmission elements a certain amount of play cannot be avoided.

With the equipment mentioned, therefore, distance simulation is associated with a series of errors and inaccuracies and only an accuracy in the order of 1% to 0.1% can be expected. Referred to absolute values, therefore, the minimum detectable distance unit is in the order of several centimetres.

Simatic position control

For the reasons mentioned above, therefore, a digital position control with static elements of the Simatic* system was developed for the shear gauge of light-section rolling mills. With these components the control speed and the number of possible switching cycles is

* Trade-mark

about three orders of magnitude greater than the apparatus employed so far. A considerable increase in accuracy is thus obtained. The following control system was set up (Fig. 1):

The gauge head moves along a toothed rack. A pinion on the gauge engages in this toothed rack and drives a disc on the periphery of which are arranged 80 small permanent magnets of alternate polarity.

With the aid of two Hall generators [1], which are displaced by 90 electrical degrees with respect to each other, the permanent magnets are scanned without physical contact being made. If the gauge is now moved by the drive motor, the two Hall generators produce via their amplifiers two impulse trains which are also displaced by 90 electrical degrees with respect to each other. Owing to the similar phase position of sine and cosine, this impulse series is known as a sine-cosine code. It is now easy to determine the direction in which the gauge moves and to emit a counting impulse for each distance unit. The pinion is such that one impulse is produced every millimetre. Such an arrangement, which produces "digital" impulses out of the "analogue" rotating movement of the disc, is called an analogue-digital convertor (Fig. 2).

The signals for forward and reverse movement of the gauge and the counting impulses are fed into a five-digit decimal counter which can count forwards and backwards, i.e. both in the positive and negative direction. The distance from the gauge to the shear is detected in numbers, i.e. digitally.

With the Simatic system only two signal conditions are used, namely the 0 and the L signal [2, 3]. Thus numbers can at first be represented only on a binary system. In this system the radix 2 with the two digits "0" and "L" is used instead of the radix 10 with the ten digits 0 to 9. With four binary digits, a so-called tetrad, 16 combinations are obtained, namely for the numbers 0 to 15 (Fig. 3). If, in this case, one employs only the first and the last five combinations and suppresses the 6 combinations for 5 to 10 by suitable switching networks in the counter, the 10 decimal digits 0 to 9 can be assigned to the 10 remaining combinations. A weight can also be assigned to each of the binary digits – to the lowest 1, to the next 2, to the third 4 and to the highest once again 2 –, so that the decimal number is obtained by adding the weights of one tetrad. This possibility is important when converting numerical data into a physical quantity, i.e. from digital to analogue. The binary coding of the decimal numbers described was used for the first time by Aiken.

In the Simatic system the binary digits are represented by components which have two stable states of operation. Such a circuit arrangement is known as a flip-flop, but also as bistable multivibrator or memory. For every two impulses entering at the input side one impulse is produced at the output. Four such bistable devices (tetrad) are used for each decimal digit. Simatic counters of this type can process up to 10,000 counting impulses per second. Theoretically this would permit movement of the gauge at a maximum speed of 10,000 mm/sec. In practice, however, the speed is no greater than 500 mm/sec. The counter is therefore by no means utilized to the limit of its capacity.

The power amplifiers following the counter supply the current for the numeral indication. The numbers are

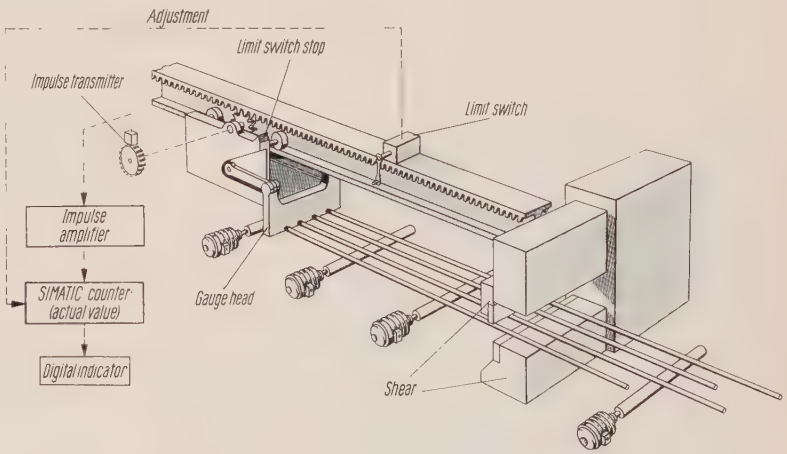

Fig. 1 Shear gauge of a light-section rolling mill. Schematic representation of the impulse initiation at the gauge

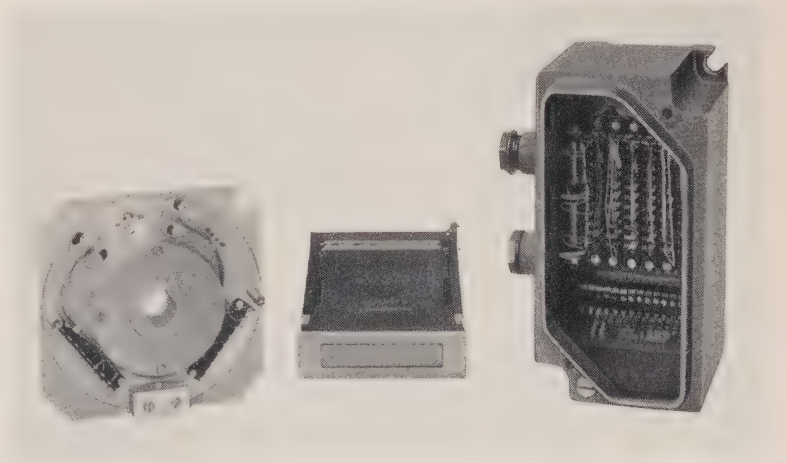

Fig. 2 Impulse transmitter, luminous window and impulse amplifier for the digital position control

Decimal number	Binary digits D C B A	Decimal digit AIKEN-code
0	0 0 0 0	0
1	0 0 0 L	1
2	0 0 L 0	2
3	0 0 L L	3
4	0 L 0 0	4
5	0 L 0 L	
6	0 L L 0	
7	0 L L L	
8	L 0 0 0	
9	L 0 0 L	
10	L 0 L 0	
11	L 0 L L	5
12	L L 0 0	6
13	L L 0 L	7
14	L L L 0	8
15	L L L L	9
	2 4 2 1	Weights

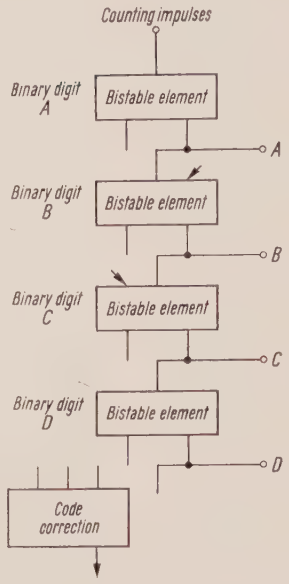

Fig. 3 A tetrad code of decimal numbers. – Left: Coding table Right: Counting tetrad

made visible by a luminous panel (see Fig. 2) with ten miniature lamps and ten miniature projection lenses for each digit [4].

In the case in question, rods with a minimum commercial length of 6 metres are to be cut. The gauge will therefore never reach the number 0, although it is the usual practice to adjust a counter by setting it in the initial position to 0. In order to make adjustment possible in spite of this, there is located at the mechanically measured distance of 6.250 metres from the shear an accurate limit switch which sends the adjusting signal 06250 to the counter. Every time this limit switch is overshot in the forward direction, i.e. in the direction of excess lengths, the counter is automatically brought into its correct position.

Accuracy

With the shear gauge described, light-section steel is cut into commercial lengths of between 6 and 24 metres. And with the SIMATIC position control the absolute tolerance over the entire range is 1 mm. This gives a minimum relative accuracy of less than 0.02%. Consequently, the cutting losses are substantially less than with the conventional position indicating equipment used previously.

The accuracy of the digital position control could also be further increased. However, it is restricted by the finite accuracy of the mechanical parts of the digital-analogue convertor and the characteristics of the machine. It is also possible to measure considerably longer distances with the same decimal accuracy using the digital counting system, for the counters can quite easily be designed with a greater number of decimal places.

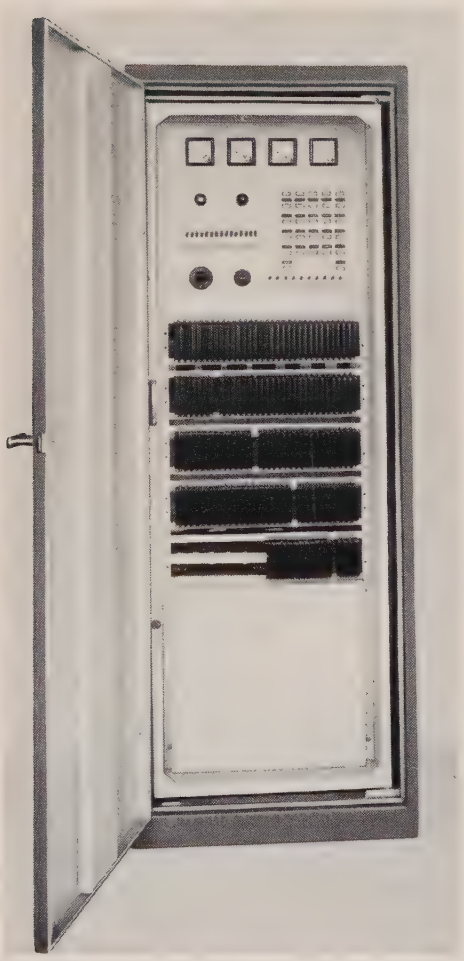

Fig. 4 Digital position control cubicle

Floating battery

In the event of a failure in the power supply, the counter would lose its information and a gauge positioning motor coasting to rest would reach a position which would then not be detected. Re-adjustment would then be necessary in each such case. This is avoided by using a floating battery as power supply for the analogue-digital convertor and the SIMATIC counter; this battery is gas-tight and requires no maintenance. The floating battery is automatically switched off only after about 30 minutes. This avoids excessive discharging of the battery and the destruction of the cells associated with it. After short interruptions in the power supply – and most interruptions are of this type – operation can be continued undisturbed.

Other possibilities

The displacement, i.e. adjustment, of the gauge can also be fully automized by counting processes. In this case one speaks of digital adjustment control. In addition to the counter unit or "actual-value register" described, which detects the momentary position of the gauge, a second unit or "desired-value register" is required in this case for the intended adjustment. The digital data for the new position is fed into this unit. The digital difference between the actual and desired values is used to control the operation of the positioning motor [5].

There is also another problem that can be solved with Simatic counters: Light-section steel, which is cut when in the hot state, for instance, must adhere to the desired dimensions after it has cooled. The cold dimension is used as the input value. In this case the corrected desired value is shaped in a suitable counting process out of the material temperature and the digital cold dimension input value.

Fig. 4 shows a cubicle for the digital position control.

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Generating Sets for Feeding X-ray Equipment

By Günther Jäger

During the last few years, many mobile or transportable X-ray units for mass radiography have been developed, which are mainly intended for overseas and underdeveloped countries. To make them independent of the public system, standard Siemens generating sets can be used to provide the necessary power. Fig. 1 shows a generating set mounted on a trailer for transport.

The blackening caused by X-rays on a photographic emulsion is the more intense the higher the tube current, the longer the exposure and the higher the tube voltage. The tube current I (in mA) and the exposure time t (in sec.), and therefore also their product It (in mAs) influence the blackening of the photographic emulsion linearly. The tube voltage U (in kV) affects the blackening much more strongly, producing a change to approximately the 5th power of that obtained on a change in current. Even a slight change in the voltage required for operation is accordingly sufficient to make the X-ray photograph useless.

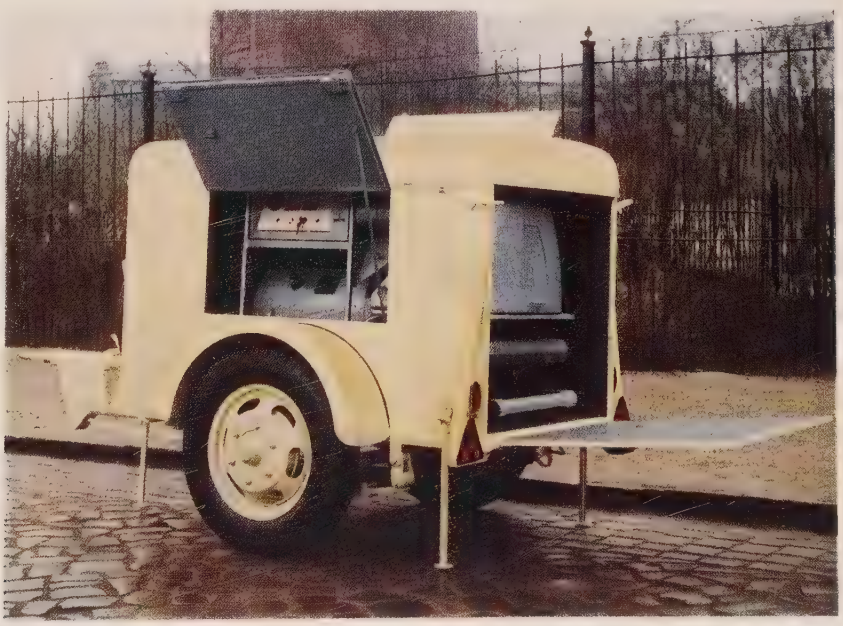


Fig. 1 Generating set for single-phase a.c. 12 kVA, 220 V, 50 c/s, 3,000 r.p.m., with air-cooled four-stroke petrol engine. The generating set is mounted on a trailer

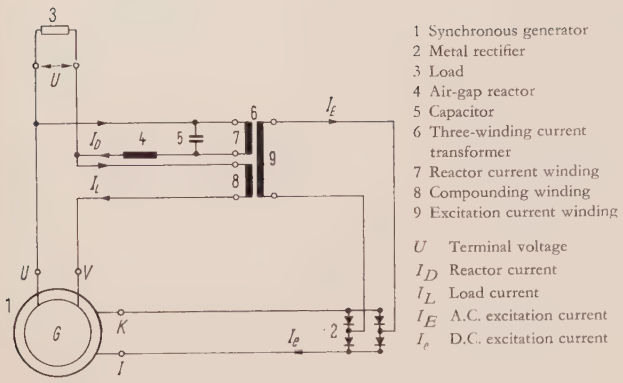


Fig. 2 Basic circuit diagram of a single-phase constant-voltage synchronous generator

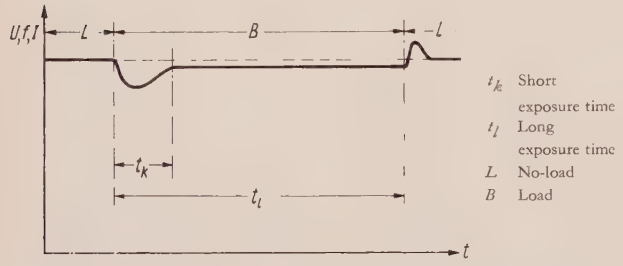


Fig. 3 Voltage U and frequency f of the generating set and also the tube current I as a function of the exposure time t with normal speed governor on the prime mover

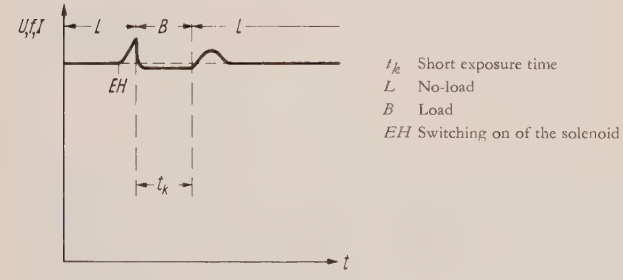
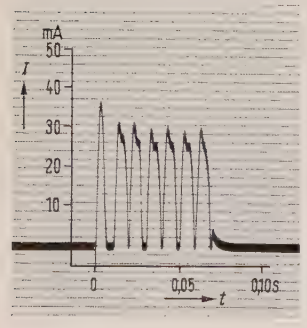


Fig. 4 Voltage U and frequency f of the generating set and also the tube current I as a function of the exposure time t with electromagnetic speed control of the prime mover



Tube current 30 mA
Exposure time 0.07 s
Tube voltage 125 kV

Fig. 5 Oscillogram of the X-ray current of a mobile X-ray unit

In view of the different thicknesses involved, every organ to be X-rayed calls for different magnitudes of the above values for the correct exposure of the photographic emulsion. The greater the distance that must be selected between the X-ray focal spot and the object for medical reasons, the greater is the value to which the tube voltage and the product mA s must be set.

It is therefore essential that the correct product mA s and the correct tube voltage be set before every exposure, both values, like the tube current, having to remain constant throughout the exposure period. These values are laid down by the manufacturer in the form of an exposure table. To enable medical comparisons to be made, the values, once set, must always be reproduced by the X-ray tube in exactly the same magnitude.

The exposures for X-ray photographs are short, ranging from a few millisecs to several seconds. During this time, the full output of the X-ray apparatus is required, and the generating set is accordingly subjected to a surge load. An additional difficulty in this connection is that the power factor of the various X-ray units lies between 0.5 and 0.9.

The standard Siemens generating sets are equipped with constant-voltage synchronous generators and conventional internal combustion engines. The generators operate on the Harz system. A three-coil current transformer ensures safe initiation of self-excitation through an air-gap reactor and a capacitor; it also supplies the no-load excitation current for the generator as well as the necessary load excitation current, this being obtained through a compounding winding which carries the load current. The interaction of the reactor and compounding windings of the transformer produces a constant generator voltage which is largely independent of the electrical power factor (Fig. 2).

By over-dimensioning the iron cross-section of the current transformer, the flux density is kept far below the saturation point. Particularly on transient surge loads with a poor power factor, as encountered with X-ray equipment, this ensures a sufficient reserve of excitation current to enable the voltage to be corrected. It returns to its rated value after only a few cycles. The speed of correction also results from the fact that the increased excitation current is fed to the generator the moment the load current is switched on.

The development of the speed governors for the prime movers has likewise made great progress. The fuel supply to the engine is increased and the speed corrected in a very short time after a load surge.

It was mentioned above that voltage and frequency of the generating set must remain constant for an X-ray exposure. This accordingly only applies for the load period; between no-load and load on the generating set, on the other hand, a voltage and frequency drop of a few per

cent can be readily accepted. The X-ray equipment must, however, be attuned to this drop with the associated generating set before being put into operation. What matters in all cases is that the product mAs can be set for any exposure time.

For low-powered X-ray equipment, the exposure times must be longer than with larger units to obtain the same degree of blackening. Fig. 3 shows the voltage and frequency of a generating set and also the tube current as a function of the exposure time when using a normal speed governor on the prime mover.

The initially slight decrease in voltage, frequency and tube current after switching on has no great effect when the exposure time is long, so that voltage and frequency can be taken as constant. If, however, exposures, e.g., of moving organs, must be made in a very short time, the conventional speed governors no longer suffice. As Fig. 3 shows, the tube current (in mA) is not constant during this short exposure period. In this case the fuel supply to the prime mover must be controlled electromagnetically by means of a solenoid valve. The fuel is set to produce no-load frequency and voltage with the solenoid de-energized and to produce the corresponding on-load values with the solenoid energized. The solenoid is energized a few tenths of a second before the X-ray exposure is made. This not only overcomes the time constant of the prime mover for regulating the speed before the surge load occurs, but also slightly increases the speed, and thus the voltage. The voltage and frequency then delivered by the generating set during the surge load are constant after about half a cycle. Fig. 4 shows the voltage and frequency of the generating set and also the tube current as a function of the exposure time when employing electromagnetic control of the speed of the prime mover. Fig. 5 shows an oscillogram for an X-ray current of 30 mA during an exposure time of 0.07 s at a tube voltage of 125 kV as obtained with a standard mobile or transportable X-ray unit. It can be clearly seen from the oscillogram that the tube current remains constant for the entire exposure time after as little as half a cycle. The constancy of the tube current is thus guaranteed even where exposure times are short.

Low-oil-content Circuit Breakers with an Insulation Rating of 10 kV and with Increased Rupturing Capacity

By Jürgen Homp

In line with the Recommendations of the IEC (International Electrotechnical Commission), the rated voltages, rated rupturing capacities and rated currents of circuit breakers have been standardized in DIN (German Industrial Standards) 43612. On the basis of these standards, a low-oil-content expansion circuit breaker has been developed for 6 kV, 250 MVA and for rated currents of 630 and 1,250 A.

The new breaker has the following technical data:

Insulation rating	10 kV	10 kV
Rated voltage	6 kV	6 kV
Rated current	630 A	1,250 A
Rated rupturing capacity	250 MVA	250 MVA
Rated breaking current (symmetrical)	24 kA	24 kA
Rated making current	68 kA	68 kA
Max. permissible surge current (crest)	75 kA	75 kA
Rated short-time current (r.m.s.)		
1-sec.	30 kA	30 kA
4-secs.	15 kA	25 kA

The clearances between the live parts of adjacent poles and the clearances to earth are such that the values for the rated alternating impulse withstand voltage correspond to the new VDE Specification 0111/2.61 § 16.

The method of arc quenching using Expansin, which has proved reliable in over 100,000 circuit breakers, is also applied by the Siemens-Schuckertwerke in this breaker.

The resilient quenching chamber operates in the usual manner in the breaker vessel of cast resin. The breaker pillars are fixed to the rear of the operating mechanism by means of cast-in bolts. The individual pillars can be easily removed, thus considerably simplifying maintenance of the breaker. Another advantage of the new type of construction is the low overall height of the circuit breaker. With a height of 740 mm, it is 50 mm lower than the former model, although the rated rupturing capacity has been raised by 25 per cent. The width is 660 mm, the depth 550 mm and the distance between the pole centres is 210 mm.

The cast-resin insulators are corrugated to increase the creepage distance. The resistance to surface leakage is thus considerably increased, particularly in the event of severe atmospheric pollution and moisture condensation. Owing to the excellent workability of the cast-resin it

Low-oil-content expansion circuit breaker H 512, insulation rating 10 kV, rated voltage 6 kV, rated current 630 A, rated rupturing capacity 250 MVA

was possible to construct breakers with which its particular advantages compared with porcelain could be fully utilized. The breaker is of rugged construction and has a high mechanical strength, which precludes any danger of breakage. Cast resin also has a high arc resistance so that, even in the event of flashovers, damage to the breaker vessels is avoided.

In the station-service systems of power stations, e.g. at the feed-in point, circuit breakers with high current ratings are required. For this reason the series has been extended to include a breaker for 1,250 A which can, however, take a continuous load of 1,600 A. When the breaker is closed, an auxiliary contact chamber of cast resin arranged in shunt behind the breaker pillar carries two thirds of the load current. When the breaker is tripped, the auxiliary contact opens first without drawing an arc so that the total current flows momentarily through the main arc-quenching chamber.

The positively coupled operating mechanism can be actuated manually by means of a detachable lever. For larger installations, where the breakers are operated and controlled from a central control room, a compressed-air operating mechanism is recommended. A third possibility is the recently developed motor operating mechanism.

SIMATIC Timers for Spot Welders

BY ROLF BARDENBACHER

Spot welding is a method which can be used successfully in all cases where metal parts are to be joined quickly and permanently. Generally, the working cycle of a spot welder is controlled by electronic devices which automatically control the movement of the electrodes and the welding current according to a time programme (Fig. 1). Where stringent requirements as to the strength and the appearance of the welded joint have to be fulfilled, synchronous ignitron controls are used [1, 2]; however, for sheet-metal work asynchronous control is generally sufficient, this being considerably cheaper owing to its simpler design. This article deals with the latter type of control.

The working cycle of a series spot welder is generally divided into four parts consisting of the following:

Squeeze time The electrodes are brought in contact with the work piece and the electrode pressure is raised up to the welding pressure

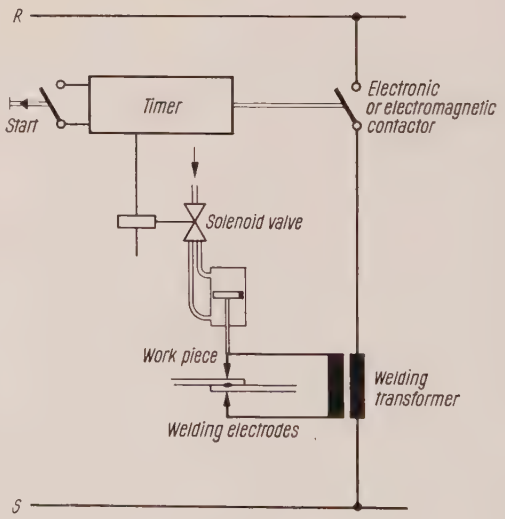


Fig. 1 Schematic representation of a spot welder with automatic repeat control

Weld time	The welding current flows and the nugget is formed
Hold time	The application of electrode pressure on the work piece is maintained, the nugget solidifies and cools off
Off time	The electrodes are separated and release the work piece

In series spot welding this cycle is repeated until the starting button is released.

An automatic control which fulfills these requirements can be constructed in a simple and neat manner with Simatic* components [3]. The stages for the four timing periods can be seen from the block diagram (Fig. 2). The time stages consist of Simatic time flip-flop units with *RC*-elements. The timing periods can be set by rotary rheostats or step switches, and are adjustable over a range from 2 to 20 cycles. It is also possible to design timing units for periods of more than 20 seconds.

In series spot welding the operating cycle is repetitive so that the off time period is immediately followed by a squeeze time period.

In single spot welding the switch *S* is not closed. Each time a new spot weld is to be made a new starting signal has to be initiated. For other applications which require more than four timing periods the operating cycle can be extended as desired.

Relays which are controlled from Simatic power stages *P* are provided for operating the welding contactor and solenoid valve.

In designing the device the requirements in industrial operations were taken into account (Fig. 3). The setting elements for the four timing periods are arranged at the front. The off-time potentiometer is coupled with the selector switch for series spot and single spot welding. The setting controls have a slotted-head drive which prevents, or at least makes difficult, inadvertent readjustment of the timing periods as sometimes happens with rotary knobs. A pilot lamp indicates whether or not the device is energized. The mains voltage and the control leads are brought in from below through a multipole coupler.

Several devices of this type have been in service for more than two years in a large motor-car factory and have given satisfactory performance at a spot frequency of about 500,000 per month.

* Trade-mark

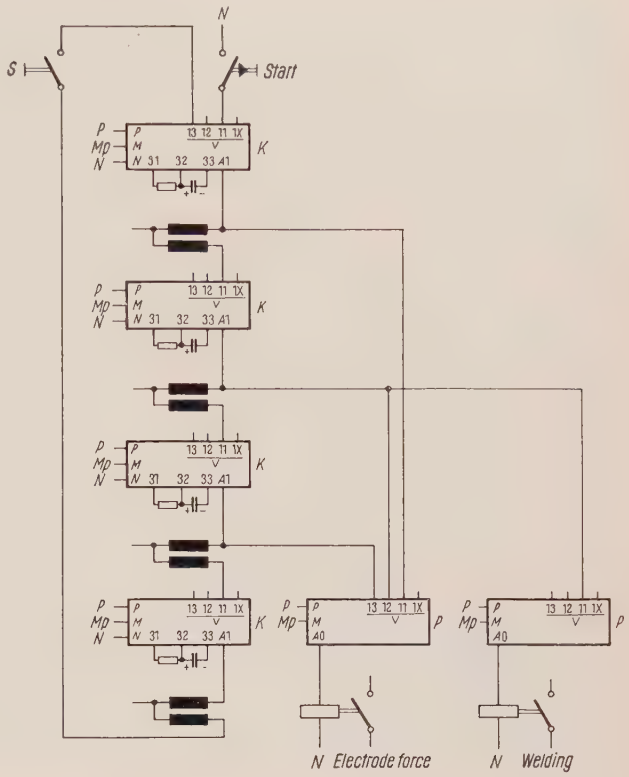


Fig. 2 Block diagram of the Simatic four-period automatic-repeat timer (*Mp :* neutral)

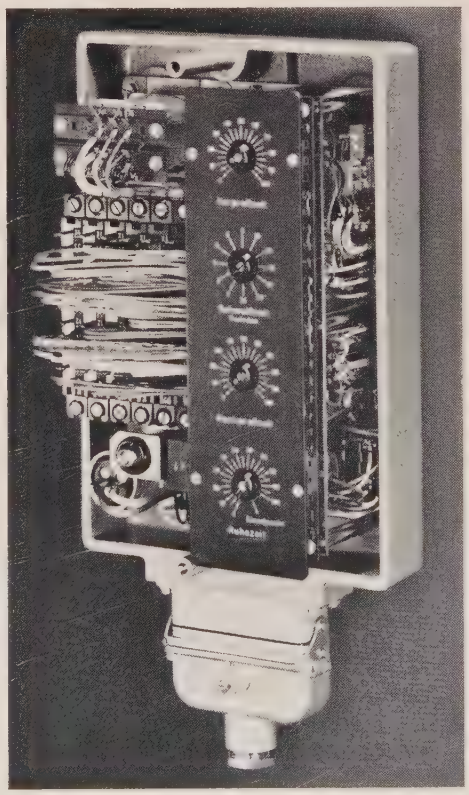


Fig. 3 Simatic timer (cover removed)

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[2] Liegmann, E.: Ignitronsteuerungen in Simatic-Bauweise. Siemens-Zeitschrift **34** (1960) pp. 239 to 241

[3] Weitbrecht, W. and Sinn, G.: Aufbau des Simatic-Systems. Siemens-Zeitschrift **33** (1959) pp. 598 to 606

Activities of the Wernerwerk für Bauelemente

BY GERHARD HÜBNER

Few branches of electrical engineering are undergoing such lively development as the components branch, where new potential applications are being discovered almost daily.

The Siemens organization has long devoted considerable attention to work on this sector, and its Components Division – known in German as the Wernerwerk für Bauelemente – is responsible for all problems of basic research, design, production and distribution.

The rapid progress made in the components sector is reflected in the Division's numerous laboratories, where staffs of experienced chemists, physicists and engineers are at work on the development of new materials and new production methods.

The steady expansion of the field of application of components has resulted in the corresponding extension of our line of types. Three development trends will here be discerned: improvement of electrical characteristics, miniaturization, increasing penetration of the microwave range. – This will now be illustrated with the aid of a few examples selected from our wide range of products.

The use of plastic foil as a dielectric has made it possible to construct capacitors of subminiature and microminiature size. Of the various magnetic materials, the use of ferrites for the cores of coils and transformers secures a marked improvement with respect to width of frequency range, small space requirements, and low losses. In building modern communications equipment, considerable space is also saved through the use of printed circuits.

New design concepts for transmitting tubes – such as meshed construction and metal-and-ceramic encapsulation – have opened the way to new microwave applications. The frame grid technique has won a position of similar importance for amplifier tubes, and permits, among other things, the construction of disk-seal tubes operating at frequencies up to and beyond 7 gigacycles without the abandonment of the conventional grid drive.

The most remarkable of the solid-state devices is the microwave transistor. Mesa transistors fabricated by the Siemens Components Division are outstanding for their high admissible dissipation, high power gain and good noise characteristics up to 300 mc. The tunnel diode – one of the newest solid-state devices – has a falling characteristic that makes it suitable as a two-pole amplifier.

Fig. 1 Main building of the Siemens Components Division in Munich

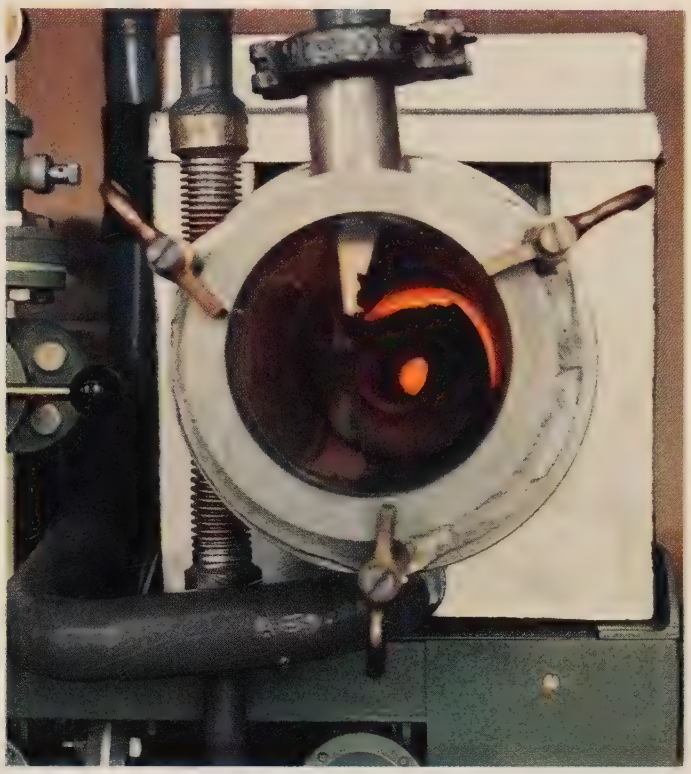

Fig. 2 Coils and transformers are among the classical components of communications engineering. The smallest coils have to be made with the aid of complex winding machines

Fig. 4 Production of deposited carbon resistors. Carbon is deposited on the ceramic forms in special furnaces: in a hydrocarbon atmosphere the crystalline glance coal forms a deposit on the base material of the resistor at high temperature

Fig. 3 Sintered metallic-oxides produced by the Siemens Components Division under the name of Siferrit* occupy a place of high importance as core materials for coils and transformers. The sintering process in the furnace makes the Siferrit as hard as porcelain. (Since it shrinks by as much as 17% during sintering, exact shrinkage calculations are essential in the production of ferrites of high gage accuracy)

* Trade-mark

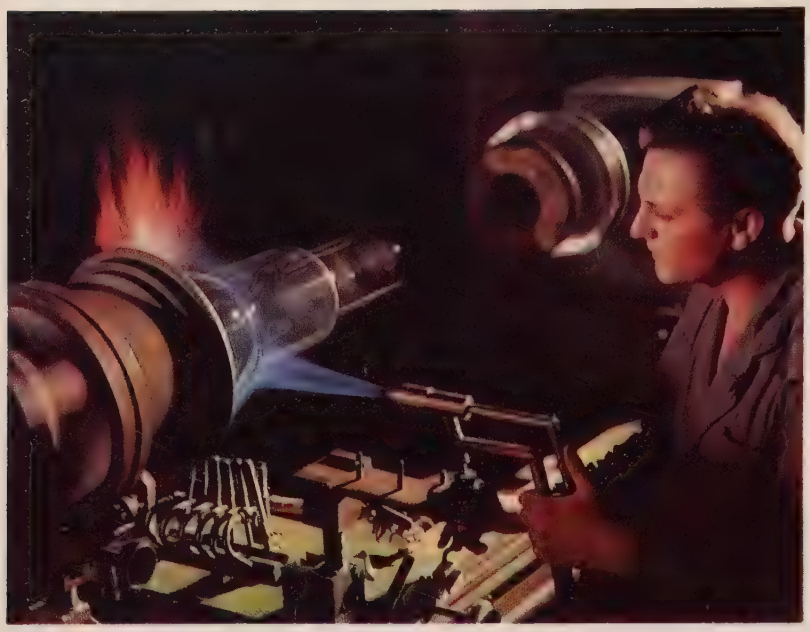

Fig. 5 The glass parts of high-power transmitting tubes are sealed to the metallic anode structure on a special lathe-type jig – an operation demanding great skill and experience

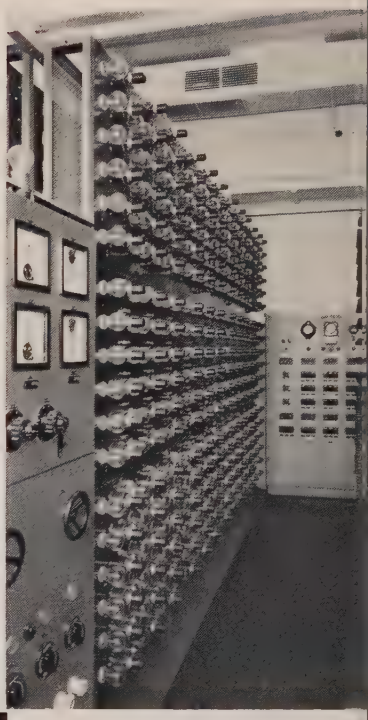

Fig. 6 The electric spot welding machine for radio and television tubes automatically welds the leads to the mount

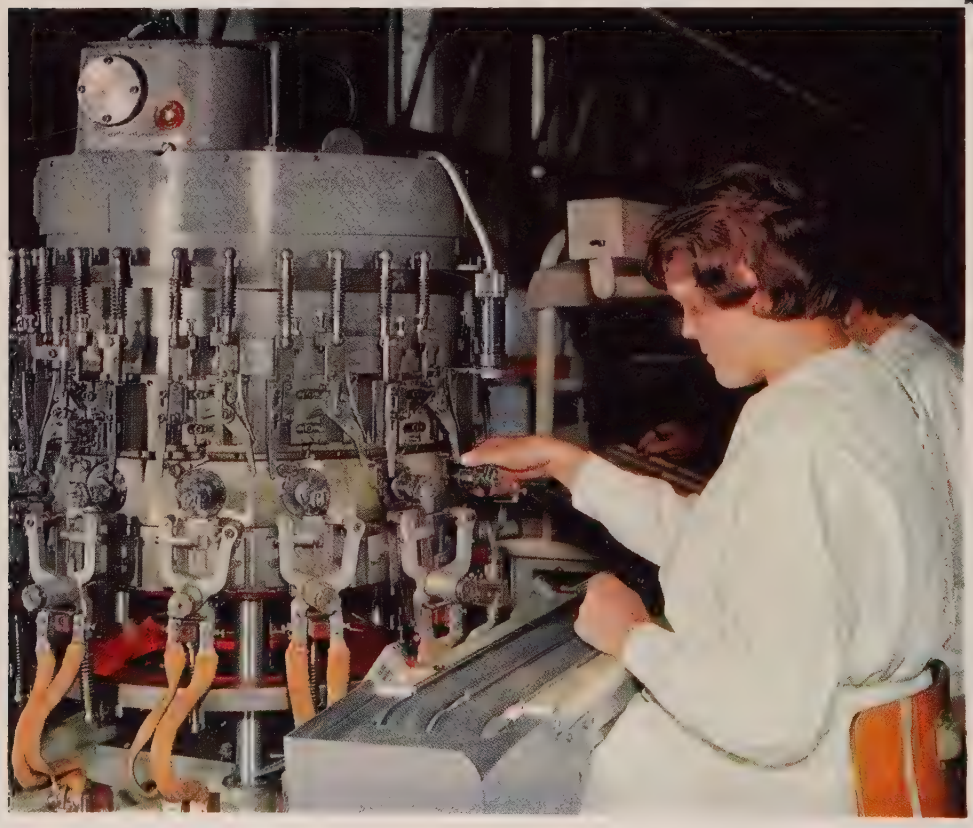

Fig. 7 Communications tubes undergoing a life test. The stability of the electrical characteristics of the tubes is observed for a long spell of operation during which periodic tests are performed

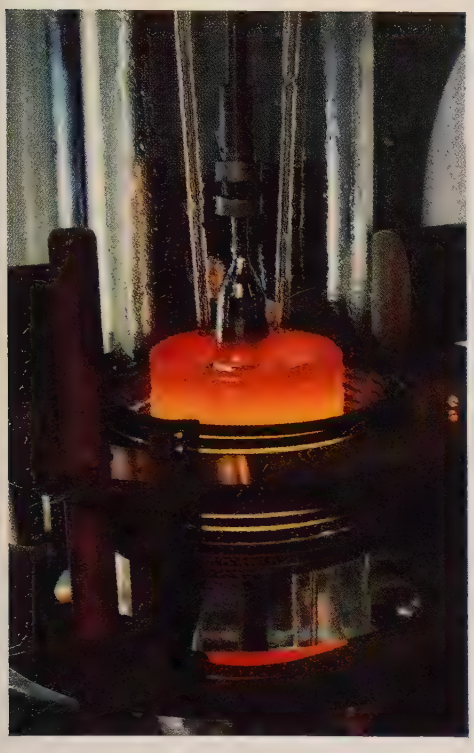

Fig. 8 Retraction of a single-crystal germanium ingot from which diodes and transistors are made

Fig. 9 During the fabrication of mesa transistors, tiny strips of gold and aluminum are vaporized upon a germanium wafer. The micro-miniature dimensions – the structure of a mesa transistor has a lateral length of only about 0.1 mm – demand the greatest care in adjusting the evaporator mask in the vacuum furnace

Fig. 10 During final assembly, the structures of the transistors are placed in the capsules. The jig here seen makes all the solder joints in a single operation

NEW EQUIPMENT

Indoor Luminaires for Xenon Lamps

BY HANS WEIK

The requirements to be met by the quality of illumination, as laid down for indoor lighting in DIN (German Industrial Standards) 3035, refer not only to the level of the illumination, but also, among other things, to the colour of the light which must be such that the colour reproduction is neither unnatural nor misleading. In various branches, e.g. in the textile and paper industries, printing and in the chemical industry, accurate recognition and matching of colours is often of great importance. In such locations, the spectral composition of the artificial light must be as near as possible to that of natural daylight.

Until now fluorescent lamps of the daylight type were generally used in such instances. Today, however, a host of new possibilities for illuminating even large rooms inexpensively with natural daylight of any desired illumination level have been created by the development of the OSRAM high-pressure long-arc xenon lamp.

High-pressure long-arc xenon lamps are at present available with ratings of 6, 10, 20 and 65 kW. The lamps consist of a relatively thin-walled quartz tube filled with xenon and are superior to all other artificial light sources with regard to the colour of their light which is very similar to natural daylight.

A voltage of approximately 50 to 90 kV (depending on lamp type) is required momentarily for igniting the lamp. The lamp current is limited by a series choke.

Xenon lamps have already given excellent service in various floodlighting installations and in the illumination of large squares etc. For indoor lighting purposes, only the lamps of lower rating are considered for the time being.

The experience gained with the xenon floodlight (LICHTFLUTER*) and with street-lighting units proved to be of great value in the development of the first indoor luminaire for xenon long-arc lamps with ratings of 6, 10 and 20 kW. In many respects, however, entirely new problems had to be solved. The luminance, for instance, with the 6 and 10-kW lamps is 140 stilbs (compared with 0.6 stilbs with a 40-W fluorescent lamp) and the surface temperature of the xenon lamps can rise to about 700 °C. Various studies and experiments had therefore to be made in order to find the best form and the most suitable materials for such a luminaire.

The luminaire (Fig. 1) consists of two main parts: the end sections, which are the same for all models, and the centre frame. A sectionalized panel of heat-resistant glass absorbs the ultraviolet rays which would otherwise be emitted directly downwards

Fig. 1 Indoor luminaire with high-pressure long-arc xenon lamp

by the lamp. Unless otherwise specified, the frame is left open at the top so that a uniform light distribution is obtained.

By using SI-ALOX* specular reflectors of various shapes, a high concentration of the light or a wide angle light distribution can be achieved at right angles to the lamp axis. Owing to the shape and characteristics of the lamp, there is a wide angle light distribution parallel to the lamp axis.

The louver baffles provide a low shielding angle.

Except for the lamp supply leads (from the remotely installed choke), the circuit arrangement used (Fig. 2) requires no other leads for control. The starter is of the normal glow type as used with fluorescent lamps.

The new luminaires have a very wide and varied field of application. The excellent characteristics of xenon light will further increase the potentialities of the new luminaires in the lighting of large rooms, e.g. picture galleries, congress and exhibition halls, etc.

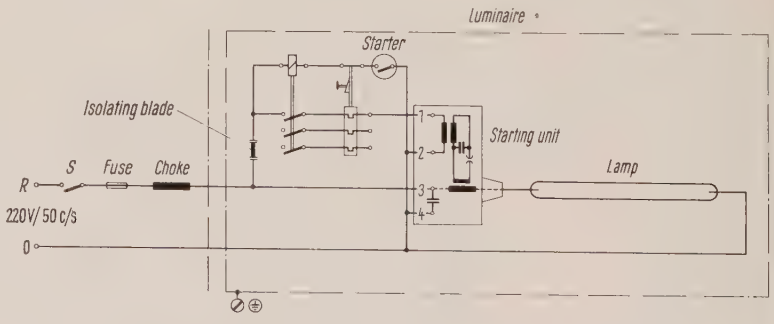

Fig. 2 Circuit arrangement of starter for 6 and 10-kW xenon lamps

* Trade-mark

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SIEMENS **U.D.C.** 621.311.21:621.67:621.316.719.2

ALBRECHT HAFFA

Dynamic Braking of Pumped-storage Units

4½ pages, 5 figures, 1 table, bibliography

Siemens Review XXVIII (1961) pp. 251 to 255

The dynamic braking of reversible pumped-storage units is being employed on an ever increasing scale in cases where quick changeover is required from turbine to pumping operation, without the use of starting turbines. The theoretical principles are discussed with the aid of an example.

SIEMENS **U.D.C.** 621.318.56

DIETER MURMANN

Relays for Telegraph and Signaling Equipment

5½ pages, 8 figures, bibliography

Siemens Review XXVIII (1961) pp. 255 to 260

Various types of relays are today used in large numbers for the control and indication of a wide range of different operations. This has resulted in steadily increasing production figures. The design concepts and special features of relays developed by Siemens & Halske for such applications are described.

SIEMENS **U.D.C.** 621.315.221.5/.7:620.197

WALTER JAESCHKE

Corrosion Protection for Metallic Cable Sheaths

6 pages, 10 figures, bibliography

Siemens Review XXVIII (1961) pp. 261 to 266

A description is given of the technological properties and corrosion characteristics of the materials at present used for metallic cable sheaths. This is followed by a discussion of the phenomena associated with the corrosion of cable sheaths and a study of the protective measures which are necessary. The results of laboratory tests on various types of corrosion protection are compared with practical experience gained in the field.

SIEMENS **U.D.C.** 621.395.72:621.395.74

ALOIS BRANDSTETTER AND HELMUT WAHL

Dial Office Technology and Local Network Configurations

5½ pages, 9 figures, bibliography

Siemens Review XXVIII (1961) pp. 266 to 272

A close economic tie-up exists between the configuration, size, numbering plan and dial system technique used in local telephone networks.
The paper investigates the economy limits for various types of dial office and treats the basic potentialities available in designing networks linking local dial offices. All requirements encountered in the planning of local networks of any type or size are readily satisfied with EMD dial system equipment.

SIEMENS **U.D.C.** 621.311.28:621.386.1

GÜNTHER JÄGER

Generating Sets for Feeding X-ray Equipment

2 pages, 5 figures

Siemens Review XXVIII (1961) pp. 275 to 277

Generating sets with constant-voltage synchronous alternators are used for feeding mobile X-ray equipment which is independent of the supply system. The sets are so designed that the voltage remains constant even at surge loads. With large X-ray units, the frequency can only be kept constant by electromagnetically controlling the fuel supply to the prime mover.

SIEMENS **U.D.C.** 621.316.79.083.722:621.771.272

FRIEDRICH FRÖHR AND REINHOLD SCHMIDT

Digital Position Control for the Shear Gauge of a Light-section Rolling Mill

3 pages, 4 figures, bibliography

Siemens Review XXVIII (1961) pp. 272 to 275

A digital position control constructed of SIMATIC components has been developed for the shear gauge of a light-section rolling mill, which, apart from effecting an appreciable improvement in the cutting accuracy, operates with practically no wear and thus requires little maintenance. These advantages are afforded by the use of contactless control gear. Provision can be made for automatic positioning or for automatic correction of the shrinkage.

SIEMENS **U.D.C.** 621.316.54.064.25.027.5

JÜRGEN HOMP

Low-oil-content Circuit Breakers with an Insulation Rating of 10 kV and with Increased Rupturing Capacity

1 page, 1 figure

Siemens Review XXVIII (1961) pp. 277 and 278

The newly developed range of expansion circuit breakers with an insulation rating of 10 kV for a rated voltage of 6 kV comply to standards, DIN 43612, as regards their current ratings of 630 and 1,250 A and their rated rupturing capacity of 250 MVA.
Considerable advantages are the reduced overall height of the units and the use of cast-resin breaker vessels.

SIEMENS **U.D.C.** 621.791.763.1-523.8

ROLF BARDENBACHER

SIMATIC Timers for Spot Welders

1½ pages, 3 figures, bibliography

Siemens Review XXVIII (1961) pp. 278 and 279

Electronic controls are finding ever increasing application on spot welders in the sheet-metal working industry. A description is given of a four-time setting programme for simple welding jobs. The timing circuit proper incorporates SIMATIC components and operates contactlessly thereby ensuring a high degree of operational reliability and a long life.

SIEMENS **U.D.C.** 628.94:621.327.59

HANS WEIK

Indoor Luminaires for Xenon Lamps

1 page, 2 figures

Siemens Review XXVIII (1961) p. 284

The high-pressure long-arc xenon lamp offers new possibilities for indoor lighting with artificial daylight.
A luminaire, which is suitable for a multitude of lighting tasks, has been developed for operation with these lamps. In addition to its application in industry, e.g. in textile and paper mills, the luminaire can also be used for lighting large rooms such as congress and exhibition halls, picture galleries etc.

SIEMENS